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ON THE SYSTEMATIC OPTICAL IDENTIFICATION OF THE REMAINING 3C RADIO SOURCES. I. A SEARCH IN 47 FIELDS

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ABSTRACT

Forty-seven 3CR radio sources that were either unidentified or identified only provisionally are investigated, mostly to fainter limits than the Palomar *Sky Survey*. New plates, taken with the Palomar 48-inch (1.2-m) Schmidt or the 200-inch (5-m) Hale reflector, were measured for positions of objects near each radio position. Optical identifications are made on the basis of positional coincidence alone to within $\sim 3\,\sigma$ of the combined radio and optical errors, which is of order $\sim \pm 4''$ for most fields.

Of the 47 fields, positive identifications are made for 19 objects; possible or probable identifications for 7; and 21 are still empty to the limit of our best optical material. Most of the 26 positive or probable identifications are galaxies. Of these, 10 are in groups or clusters: the best cases are 3C 268.3, 299, 324, 330, and 337. Only four probable quasar candidates (3C 36, 272, 321, and 418) are among the 26 cases. Previously suggested identifications for 3C 36, 68.2, 99, 114, 124, 175.1, 210, 228, 263.1, 289, and 356 are shown to be unlikely on the basis of positional disagreement.

Optical positions of the 26 new candidates and other stars in the fields are given. No spectroscopy or photometry is given for any of the candidates except 3C 460, where a low-spectral-resolution scan gave $z = 0.27 \pm 0.02$ for the identified E5 galaxy.

Subject headings: galaxies — quasi-stellar sources or objects — radio sources

I. INTRODUCTION

The 3C catalog (Edge *et al.* 1959), as revised by Bennett (1962), is fundamental to many problems of radio astronomy. It is important that the optical identification of the catalog be as complete as possible; or if completeness cannot be achieved, it is almost as important to understand why.

Despite great efforts by many people to obtain identifications (cf. Minkowski 1974 for a review), about 25 percent of the 3CR sources above $|b| > 15°$ are still not identified, and many of the identified sources have not been studied in any detail (Kristian and Minkowski 1974). Ten years ago the search was hampered largely by the lack of precise radio positions. However, the remarkable advances in radio astrometry begun by Adgie (1964), and carried forward by Adgie and Gent (1966), Clark and Hogg (1966), the Cambridge One-Mile Telescope group (e.g., Macdonald, Kenderdine, and Neville 1968; Mackay 1969; Elsmore and Mackay 1969), Wade (1970), Fomalont and Moffet (1971), Wade and Miley (1971), Adgie, Crowther, and Gent (1972), Douglas *et al.* (1973), and others, have produced very accurate (~ 1 arc sec) 3CR positions. Today, progress has been stopped primarily by the faintness of all of the remaining sources; many are below the routine photographic limit of the Palomar 48-inch Schmidt, and are not on the *Sky Survey* prints which have been the primary source for identification studies.

We began a deeper systematic optical survey in 1967 with telescopes of the Hale Observatories in an effort to help complete the optical identifications and to study their nature. The present paper is the first of a series. It is concerned with 47 3CR sources which were, in 1967, either unidentified or identified only provisionally. In the meantime, some of the sources have been identified by others (e.g., Wlerick, Lelièvre, and Véron 1971; Spinrad 1973, etc.). For these sources, our results provide an independent confirmation.

Of 47 sources, positive identifications have been made for 19, possible or probable identifications for another 7, and 21 fields are still either empty to the limit of our optical material, or the radio picture is sufficiently confused to prevent a unique identification. The identifications here are based solely on the agreement of optical and radio positions. No appeal to color or to the nature of the optical object is made.

II. THE METHOD

The major identification attempts of Véron (1966*a*, *b*; 1968), Wyndham (1965, 1966), the Cambridge One-Mile Telescope group (Macdonald *et al.* 1968, Mackay 1969; Elsmore and Mackay 1969), and very many others interested in specific objects, have been thorough to the routine limit of the Palomar *Sky Survey*. To make progress in the fields that are still empty requires deeper plate material.

We have taken such plates with the 48-inch Palomar Schmidt telescope using IIIaJ plates (usually with a Wratten 4 filter with $2\frac{1}{2}$-hour exposures) and with the 200-inch Hale reflector using either 103aD+GG11 ($\lambda\lambda$5000–6500), 103aE+RG1 ($\lambda\lambda$6100–6800), or a single stage electrostatic image tube with RG1 filter ($\lambda\lambda$6100–8000).

The fields were chosen to have accurate published radio positions, and all of the radio lists mentioned in § I were used where the radio positions were determined to better than $\sim 3''$ in both coordinates. Some radio positions are known to a considerably higher

TABLE 1

STATUS SUMMARY OF EACH FIELD

Field	Status	b^{II}	Type	Best Plate	Comments
3C 14	New id	-44^{o}	?	48-3aJ; 200IT	5″ (2.7σ) agreement. Possibly diffuse.
19	New id	-30	G	vg 3aJ; 200R	Many ft galaxies. 2.″2 positional agree. Independent id Veron
36	New id	-17	Q	200R	4″(<2σ) posn. Relat. blue, compact
42	New id?	-33	?	48-3aJ	May be multiple. Assoc with extremely faint objects? 1″ in RA; 5″ in Dec.
49	New id	-47	G	200 V	Fuzzy and elongated.
54	Possible new id	-18	G	200V, 48-3aJ	Smudge near 200V limit poor plate at center of the double radio source.
65	Still empty	-20		200R	Object B on chart is a galaxy at $\Delta\alpha = 11.^{s}9W$ and $\Delta\delta = 12.''7S$ of rad. posn.
68.2	Still empty	-26		PSS	Star near position with V = 15.32, B-V=0.69, U-B=0.07
99	New id	-37	N or Compt. G	200R; 200V	Image softer than stars on excellent 200" plate but harder than normal nearby galaxies N or Q?
105	Still empty?	-34	G?	200RIT	Smudge at limit of poor 200.
107	Extended smudge?	-35	G?	200D poor seeing	Extended smudge that looks real at poor rad posn.
114	Id? double radio	-22	?	48-3aJ	Object C near one part of double radio source. Wyndham id wrong.
124	Still empty	-28		Fair 200R	Galaxies nearby (A, H)
152	Still empty	- 1		48-3aJ; Fair 200IT	
172	Filaments	+13		Light 200V	Wyndham's choice L has stellar colors
175.1	Still empty	+12		Fair 48-3aJ	Object C is a galaxy. N4″ from rad. pos, but photometry and spec show it to be a star.
194	Id	+32	G?	Poor V200"	Parker's (Mackay 1969) id confirmed.
210	Still empty	+39		V poor V200"	Old id by Wyndham NG. Suggestion at plate limit.
225	Id. ?	+44	G, G	Good 48-3aJ	Two gal? at two rad. components?
228	Still empty	+46		Blue 48-shallow	Old ID's NG. Obj A of Sand & Wyndham blue but far from pos.
238	Still empty	+47		Fair 48-3aJ.	
241	Still empty	+56		Routine 48V	Nothing within 1 arc min.
249	Still empty	+51		Fair 200V	
250	Still empty?	+67		Routine 48B	Wyndham (1966) Wills and Parker (1966) id's NG.
255	Still empty	+53		Good 200V	
263.1	Prob. id.	+74	G	IT 200R	Prob. gal. Wyndham's id NG.
268.1	Complicated Galaxies in field	+44		200V (fair) IT 200R (good)	confused
268.3	New id	+52	G, cl	200IT (good)	
272	New id	+74	Q	200IT (VG)	Two plates show image
275	New id	+58	G, cl	48-3aJ	Galaxy; possibly in cluster
280	New id	+70	G, cl	200V (VG)	Possibly in cluster
289	Still empty	+65		200IT (E)	Wyndham's id NG.
294	Still empty	+72		200 V(E)	Not star D
297	Pos. id.	+52	G, cl	200IT (E)	Poor rad. pos. but cluster of v ft. gal. near.
299	New id	+67	G, cl	200IT (VG)	Brightest gal in cluster. Dumbell?
305.1	New id	+39	G?	200IT (VG)	At limit.
321	New id	+54	Q?	200IT (VG)	Star like object
324	New id	+49	G, cl	200V (F), IT	At limit of shallow V
326.1	Prob still empty	+47		48-3aJ; 200IT	Star 11″ ± 4″ from rad posn.
330	New id	+41	G, cl	200IT (F)	In faint cluster
337	New id?	+44	G, cl	200V (G)	200-inch shallow
352	New id	+36	G	200V, 200IT	Close to star D.
356	Confused	+34	Ft cl?	200IT (G)	Wyndham id NG.
418	New id	+ 6	Q	200 R(E)	Red object. Sharp QSS?
437	Still empty	-28		48-3aJ	
458	Identified?	-50	vfG	200IT (G)	
460	Id confirmed	-35	G, N	200R (E)	Id by Wlerick et al. (1971).

NOTES TO TABLE 1: DETAILS OF EACH FIELD

The nature of the identified object, or the character of the remaining empty field, is summarized here for each source as an aid to further photometric and spectroscopic work.

3C 14.—Identification (ID) likely on the basis of 2″ (1 σ) position agreement. (This differs from the number given in table 1, and is based upon an improved unpublished radio position by Adgie and Gent.) Nature uncertain. Looks stellar on 200-inch red image-tube plate, but somewhat diffuse on 48″ IIIaJ and 200-inch *V* image-tube plates. Many faint galaxies nearby. Independent ID by Wlerick *et al.* (1971). Wyndham's (1966) original ID is confirmed.

3C 19.—New ID with galaxy from position agreement of 2.″2 = 2 σ. Cluster? Véron (private communication) independent ID confirmed here.

3C 36.—ID based on 4″ (< 2 σ) position agreement. Tentative ID as quasar based on relatively blue color and compact nature. Near limit of 48-inch blue, 200-inch red plates. Suggestion by Véron (1966*b*), "A," invalid on basis of position discrepancy of 10″ (> 4 σ) and photometry (table 4).

3C 42.—Likely ID on basis of position agreement of 2″ in decl., 2″ in R.A. May be extended or multiple on 48-inch IIIaJ, and may be connected to other faint objects south and west. If the latter are real, one of them may be a better ID. Same ID here as by Wlerick *et al.* (1971).

3C 49.—ID on basis of < 1″ agreement. Nature uncertain: galaxy? Looks fuzzy on 48-inch IIIaJ, 200-inch red plates but more stellar on 200-inch V. ID by Wlerick *et al.* (1971).

3C 54.—Possible ID. Very faint extended image near center of line between components of double radio source. If real, it is at limit of fair 48-inch IIIaJ and poor 200-inch *V* plate. Requires confirmation.

3C 65.—Empty to limit of 200-inch red plate in fair seeing. Véron "a" (1966*b*) not the identification.

3C 68.2.—Empty to 48-inch limit except for star G, which is off-center of an extended radio source, and has normal stellar colors (table 4). E. M. Burbidge is quoted by Macdonald *et al.* (1968) as spectroscopically verifying that G is a star. Our spectra show star G to be type F8, and star H type ~F2. "G" was Wyndham's (1966) suggested ID.

3C 99.—ID on basis of < 2″ agreement with radio positions by Wade and Miley (1971) and by Adgie and Gent (unpublished). ID suggested by Wyndham (1966) is 32″ north. Red 200-inch plate and visual inspection of 200-inch Cass TV viewer shows object slightly extended in NE–SW direction. Image is soft but compact on plates. Near edge of faint extended rich galaxy cluster. A low-accuracy scan (1972 October 31) shows *N* galaxy colors: $V = 19.1$, $B - V = 1.1$, $U - B \simeq -0.7$.

3C 105.—Empty to limit of all available shallow plates. Possible smudge at radio position on a poor 200-inch image-tube plate. Needs confirmation.

3C 107.—Faint smudge near center of the "large" radio error box of Adgie and Gent (1966).

3C 114.—Macdonald *et al.* (1968) show double radio source separated by 42″ of sizes < 15″. Object C of figure 2 is within 3″ of SW radio component. 48-inch IIIaJ has very faint, unmeasurable objects near NW radio component, shown as cross in figure 2. Previous ID by Wyndham (1966) (object A in fig. 2) unlikely on basis of 11″ position discrepancy.

3C 124.—Empty to limit of 200-inch red and *V* plates in poor seeing. Galaxy A in figure 3 closest to radio position of Wade and Miley (1971), but is 31″ S of radio position. Wyndham's (1966) ID therefore unlikely.

3C 152.—Empty to limit of fair 48-inch IIIaJ and 200-inch *V* image-tube plate. Two good radio positions. Faint star SE of marked position in figure 3 is ~14″ = 10 σ away.

3C 172.—Radio source double with 86″ separation. NE component is extended ~8″ × 16″. 200-inch *V* plate shows possible filaments halfway between the two components: needs confirmation. Object L was suggested QSS by Wyndham (1966), but has stellar colors, as does object A (table 4). Region is in low latitude ($b = +13°$), but not completely obscured as galaxies are seen.

3C 175.1.—Empty to 48-inch IIIaJ limit. Star N is only 4″ from radio position, but is galactic from photometry and a spectrum by Lynds (Elsmore and Mackay 1969). Wyndham's (1966) ID as object N is therefore suspect.

3C 194.—Probable galaxy 4.″6 from peak of extended (17″ × < 8″) radio source. Parker's previous ID (Mackay 1969) confirmed. *Sky Survey* print shows object to be red. Slightly fuzzy on fair 200-inch *V* plate, but image is harder than obvious galaxies of same brightness. Also ID by Wlerick *et al.* (1971) from which position was taken for table 3.

3C 210.—Empty on 200″ *V* plate in poor seeing. Wyndham's (1966) suggested ID is 13″ from radio position and is probably a *Sky Survey* flaw. Cluster of galaxies ($N \sim 15$) eastward of radio position.

3C 225.—Two galaxies? Two radio components of unequal strength separated by 6′. The NW (weaker) component coincides within the measuring error (~3″) with a bluish circular galaxy 10″ in diameter. SE component coincides with larger edge-on galaxy near limit of 48-inch IIIaJ plate. Nothing unusual between the radio sources.

3C 228.—Empty to 48-inch IIIaJ limit. Wyndham's (1966) ID probably a plate flaw. Object A (fig. 4) suggested by Sandage and Wyndham (1965) is very blue but far from radio center ($\Delta\alpha = 31″$, $\Delta\delta = 47″$).

3C 238.—Empty to 48-inch IIIaJ (fair) limit.

3C 241.—Empty to 48-inch routine *V* limit. Nothing visible within 1 arc min. Source scintillates (Hewish *et al.* 1964) indicating structure < 1″.

3C 249.—Empty on fair 200-inch *V* plate. Possible local obscuration as deduced from low surface density of galaxies, even though $b^{II} = +52°$.

3C 250.—Empty? Radio source has two nearly equal components, 42″ apart in P.A. 55° (Macdonald *et al.* 1968). Only possible optical object to 48-inch limit is on red plate only about 10″ NW of north following radio component. It is different from the objects referred to by Wyndham (1966) and by Wills and Parker (1966). The Wills-Parker radio position is 3′ south of that of Macdonald *et al.*

3C 255.—Empty to limit of fairly good 200-inch plate.

3C 263.1.—Probable ID with object near limit of red ($\lambda\lambda$6100–8000) 200-inch image-tube plate. Needs confirmation. If real, probably a galaxy. The brighter galaxy suggested by Wyndham (1966) is too far away to be the identification.

3C 268.1.—Complicated case, still under investigation. Radio source resolved into two components of much different strength, separated by 41″ (Macdonald *et al.* 1968). The blue star C of figure 5 ("a" of Longair 1965) is 18″ S of the brighter western component. The galaxy E (fig. 5) ("d" of Véron 1966) is 17″ NE of the fainter, eastern radio component. Nothing is visible at or between the radio components on any available plate. A 200-inch *V* plate shows a suggestion of a bridge between galaxies E and g (fig. 5). A 200-inch red image-tube plate shows an extended (~7″) low-surface-brightness object near the limit, about 10″ N of the eastern radio component, and coinciding with part of the "bridge." These faint features may not be real, and require confirmation.

3C 268.3.—New ID with faint galaxy based on 1″ position agreement. 200-inch red image-tube plate shows many other faint galaxies in a very distant cluster, as suggested earlier by Parker *et al.* (1966) from red *Sky Survey* print.

3C 272.—New ID with exceedingly faint object on the line between two radio components. Remarkably, Wyndham (1966) mentions the object as a smudge at limit of blue *Sky Survey* plate. It is a limiting object for us on two 200-inch red image-tube plates ($\lambda\lambda$6100–8000). On the basis of color or variability we suggest it to be a QSS.

3C 275.—ID with galaxy in a distant cluster on basis of 3″ agreement with unpublished radio position by Adgie and Gent. Near limit of 48-inch IIIaJ. There is clearly a very distant cluster in the area.

3C 280.—ID with pair of galaxies near limit of shallow 200-inch *V* plate; one is 4.″5 E, the other 4.″5 S of the centroid of an extended (14″ × < 9″) radio source.

3C 289.—Empty to limit of red 200-inch image-tube plate, although many galaxies on plate. Wyndham (1966) and Wlerick and Véron's (1967) ID is 26″ (43 σ) from radio position, and is neutral in color (star B, table 4 here). Compare Wlerick and Véron (1967).

3C 294.—No ID. Closest object on 200-inch *V* plate is star D, 11″ W, which is a galactic star of F type (Wyndham 1966) and stellar colors (table 4). Next nearest objects are faint galaxies 40″ distant. Image of star extends to within ~4″ of radio position and could conceal a faint object. Star D is not the identification on basis of 11″ position discrepancy and spectrogram (Wyndham 1966), and stellar colors (table 4). Compare Wlerick and Véron (1967) for contrary view.

3C 297.—ID perhaps. Need better radio position, as only available have accuracies ~20″. Several faint galaxies near radio position on 48-inch IIIaJ and 200-inch red image-tube plate. *Note.*—After this paper was finished, we received accurate positions for 3C 297 by Adgie and Gent and by Browne and McEwan. On the basis of these, 3C 297 is classified as an empty field, although the source is in a rather noisy region of our best plate. This source will be discussed again in a later paper of this series.

3C 299.—Brightest member of faint cluster on basis of 2″ position agreement. The present ID is same as Wyndham (1966), and confirmed by Véron (1966). Redshift by Spinrad and Smith (1973) of $z = 0.367$.

3C 305.1.—ID with exceeding faint object, probably a galaxy, at the Wade and Miley (1971) position, near limit of 200-inch red image-tube plate.

3C 321.—Probable new ID with starlike image on 200-inch red image-tube plates within ~5″ optical uncertainty at unpublished radio position by Adgie and Gent. We assume that badly discrepant (33″) position by Wyndham (1965) is in error. Candidate not seen on 48-inch IIIaJ, suggesting it is either red or variable.

3C 324.—ID with galaxy in very faint but definite cluster ($N \simeq 10$). Position agreement to within uncertainties of ~2″.

3C 326.1.—Probably still empty. Faint stellar object ("a" in fig. 8) is 11″ ± 4″ SW of precise radio position of Adgie *et al.* (1972). Galaxy "b" is 25″ SW of this position.

3C 330.—ID with group of galaxies on line between the two components of the double radio source that is separated by 66″. Brightest galaxy of the group lies at the midpoint. This is clearly a distant cluster.

3C 337.—New ID? Source lies in an apparent absorption patch ($b^{II} = +44°$) ~ 4′ across. Radio source is double, separated by 38″. A fair 200-inch *V* plate shows four faint galaxies at the plate limit, clustered in a group ~11″ across, on the line joining the radio components.

3C 352.—ID with diffuse object within 1 σ of precise radio position of Adgie and Gent (1966), and of Adgie *et al.* (1972) that is 3.″6 E and 5.″7 S of star D (fig. 8). Visible on two 200-inch plates. Large (~4″) with hardly any central concentration. Distant cD? No obvious cluster. Compare Wlerick and Véron (1967) on D as a radio star.

3C 356.—Geometry is not clean. Two unresolved radio sources 69″ apart in position angle 161°. Star N of fig. 8, which was Wyndham's (1966) suggested ID, is 14″ NW of the southern radio component. It is a galactic star from a spectrum by Schmidt (Macdonald *et al.* 1968) and from the stellar colors (table 4 here). Star M of figure 8 is 9″ S of the northern radio component and has stellar colors (table 4). A 200-inch image-tube plate shows no other objects on a line joining the radio components. There are several faint galaxies within 25″ of M, one of which is within 2″ of the northern radio component. Can the complex be two independent sources, one empty and the other (northern) a galaxy in a cluster?

3C 418.—ID on basis of ~1″ position agreement. Object red, but latitude ($b^{II} = 6°$) is low. Excellent-seeing 200-inch *R* plate shows image to be sharp with no evidence of softness. Quasar candidate.

3C 437.—Empty to limit of 48-inch IIIaJ.

3C 458.—Faint galaxy of Wyndham (1966) is 10″ S of optical position given by him and is ~15″ SW of center of an extended triple source. Slightly fainter object (A), probably a galaxy, about same distance SE of the radio center.

3C 460.—ID earlier by Parker *et al.* (1966) as a red galaxy. Confirmed here by coincidence of positions within total errors (< 5″). ID also by Wlerick *et al.* (1971). Excellent E 200-inch plate shows elongated (E5) galaxy. Earlier searches confused by defect to east that appears only on the blue *Sky Survey* print. A single low resolution spectral scan of the central 2 arc sec of the galaxy shows emission at 4740 ± 80 Å. If this is λ3727, it gives a redshift of $z = 0.27 \pm 0.02$ which is consistent with the angular diameter of 2″ × 5″ and the scan color of $V - R \simeq 1.2$ for a normal E galaxy at this redshift.

accuracy of ~0.″5, and these were naturally given the highest weight.

Measurements of stars and galaxies near the radio positions were made with a two-coordinate long-screw engine on 48-inch plates relative to Smithsonian catalog stars. Proper motions were taken into account, and our measured positions are statistically accurate to $\sigma \simeq \pm 0.''6$, which is high enough to positively identify sources and has nearly the quality suitable for calibration purposes (cf. Murray, Tucker, and Clements 1969; Kristian and Sandage 1970).

When the special Schmidt IIIaJ plates were available, an identification could sometimes be made directly with one of the measured objects on the 48-inch plates. But often no measured optical object coincided with the radio position, and appeal was made to deeper 200-inch plates. The radio position was plotted on a transparent overlay, at the scale of an enlargement of the 200-inch plate, with respect to the measured 48-inch stars. Positions could be measured directly from the prints in this way with an accuracy of the order of 1″.

III. THE RESULTS

A summary of the results for the 47 fields is given in table 1, which includes notes for each field. The best available plate is listed in column (5), where the notation refers to the telescope (48 = 1.2-m Palomar Schmidt; 200 = 5-m Hale reflector), the plate type (3aJ = IIIaJ; *V* = 103aD + GG11; *R* = 103aE + RG; IT = image tube, etc.), and the quality (E is excellent, G good, P poor) of the best plate available. The nature of the object is listed in column (4), where G is for galaxy, cl for cluster, and Q for a starlike image that is a possible quasar.

Coordinate data for the objects measured in each field are listed in table 2. Finding charts are given in figures 1–9 (plates 1–9).

Newly identified objects are shown on these charts between two identifying bars. For the fields that remain empty, the radio positions are often indicated by crosses, circles, or ellipses. The plate type for each of the illustrations is given in the caption.

Optical positions for the newly identified objects are listed in table 3. The positions that are given with high precision (those without parentheses) were measured directly with the long-screw engine on 48-inch plates. The internal rms errors for these are $\langle\sigma(15\,\Delta\alpha\cos\delta)\rangle = 0.''69$ (if the abnormal residual of 3″ for 3C 36 is ignored) and $\sigma(\Delta\delta) = 0.''53$, as judged by the internal agreement of the independent measurements in each of the four cardinal directions. Positions listed in

TABLE 2

POSITIONS OF OBJECTS MARKED IN EACH FIELD

Field	Star	α 1950	δ 1950	Remarks
3C 14	B	00 33 29.97	+18 21 44.6	
3C 19	A	00 38 10.85	+32 54 09.9	
	B	10.11	54 03.8	
	C	09.11	53 42.5	
3C 36	A	01 15 02.58	+45 20 31.6	
3C 42	C	01 25 41.30	+28 47 51.9	
	D	39.94	47 15.4	
3C 49	E	01 38 27.97	+13 33 43.5	
	G	30.18	37 00.2	
	H	20.09	40 26.0	
	J	15.33	37 05.4	
	K	27.96	35 20.2	
3C 54	A	01 52 24.99	+43 30 57.5	
	C	29.30	31 00.4	
	D	19.59	31 16.6	
	E	27.62	31 37.8	
	F	27.84	31 40.4	
3C 65	A	02 20 34.90	+39 46 54.7	
	B	35.82	47 07.3	galaxy
	C	33.27	46 12.4	
	D	34.12	46 31.3	
	E	34.68	46 27.4	
	F	33.82	46 42.2	
3C 68.2	A	02 31 25.86	+31 20 18.4	galaxy
	B	18.19	20 20.1	
	E	18.78	20 54.7	
	F	19.45	20 22.5	
3C 99	B	03 58 33.33	+00 28 42.8	galaxy
	C	31.63	29 00.4	galaxy
	D	26.59	29 40.4	
	E	24.39	29 32.3	
	F	23.57	30 20.5	
	G	19.97	29 33.8	
	H	30.76	28 43.8	
	J	20.20	25 07.8	
	K	45.13	25 44.6	
	L	41.64	31 23.3	
3C 105	A	04 04 44.78	+03 31 43.9	
	B	55.27	32 22.6	not shown
	C	39.80	33 58.0	
	D	47.35	33 48.1	
	F	53.17	28 59.3	not shown
	G	33.78	30 01.9	
	H	37.39	34 44.7	
3C 107	A	04 09 47.15	-01 06 23.8	
	B	49.01	06 25.1	galaxy?
	C	49.41	06 29.7	
	F	51.00	08 12.1	galaxy
	G	48.11	08 13.5	
3C 114	A	04 17 28.34	+17 46 27.3	
	B	27.37	46 30.3	
	C	27.85	46 39.1	galaxy
3C 124	A	04 39 23.91	+01 14 51.1	galaxy
	C	23.36	15 29.4	galaxy
	F	31.36	15 38.4	
	G	30.43	15 46.3	
	H	27.26	15 52.5	galaxy
	I	29.17	17 52.1	
	L	08.87	14 19.1	
3C 152	A	06 01 30.25	+20 23 00.6	
	B	30.69	22 22.9	
	C	30.13	22 18.4	
	D	28.75	22 23.3	
	E	26.19	21 37.0	
	F	25.63	21 43.7	
	G	24.16	22 02.8	
	H	22.64	21 56.9	
	I	29.35	20 37.2	
	J	33.21	21 06.3	
	K	35.55	21 21.9	
	L	34.63	21 00.9	
	M	30.43	20 50.3	
	N	23.17	21 35.8	
	O	22.33	22 28.2	
	P	31.10	22 38.0	
	Q	37.85	22 25.4	
	R	32.88	19 54.9	
3C 172	A	06 59 02.47	+25 17 21.2	
	B	04.03	17 12.2	
	C	05.54	16 57.3	
	D	05.92	18 29.4	
	E	05.91	18 55.4	
	F	04.59	18 36.2	
	G	58 52.60	18 41.9	
	H	59 00.84	17 20.6	
	I	07.36	15 50.2	
	J	09.75	17 59.7	
3C 175.1	A	07 11 16.14	+14 43 03.1	
	B	14.98	42 38.4	
	C	16.07	42 41.2	galaxy
	E	17.70	42 43.5	
	F	17.59	42 31.8	
	H	14.76	42 06.0	
	I	16.68	42 04.2	
	J	17.29	42 06.5	
	K	18.16	42 06.3	
	L	12.47	43 44.5	
	M	13.17	41 10.3	
	N	14.37	41 29.9	
3C 194	B	08 06 39.43	+42 35 30.3	
	C	37.83	35 44.7	
	D	27.71	35 08.4	
	E	27.05	38 05.2	
	F	47.06	34 55.3	
3C 210	B	08 55 14.48	+28 03 49.2	
	C	14.34	03 31.4	
	D	15.21	03 25.1	
	E	27.20	01 26.9	
	F	09.24	00 31.7	
	G	54 53.40	03 50.6	not shown
	H	55 12.16	04 36.0	
3C 225	A	09 39 31.06	+14 00 22.3	
	B	29.42	00 22.2	Veron a
	F	44.79	+13 57 02.6	
	G	43.36	+14 00 45.9	
	H	44.64	01 02.0	
	I	28.50	03 13.5	
	J	04.90	00 36.5	
	K	20.62	+13 58 18.5	
3C 228	A	09 47 25.49	+14 34 39.8	
	B	25.61	34 45.7	
	C	27.66	35 35.8	
	D	29.73	35 59.3	
	E	21.08	33 35.7	
	G	21.70	28 41.1	
	H	42.84	31 31.0	
3C 238	A	10 08 14.15	+06 39 17.9	galaxy
	C	19.38	39 07.1	galaxy
	D	18.13	40 27.3	galaxy
	F	12.50	40 11.9	galaxy
	G	17.27	41 09.0	
	H	17.95	39 35.1	
	I	26.98	38 42.2	
	J	23.75	41 03.4	
	K	06.77	42 57.0	
	L	09.81	36 39.0	
3C 241	A	10 19 00.45	+22 13 06.8	
	B	05.08	13 42.6	
	C	04.99	15 26.8	
	D	07.79	15 36.6	
	E	08.77	15 38.3	
	F	25.23	15 19.3	
	G	20.47	12 46.8	
	H	18 55.72	13 49.2	
	I	57.33	16 43.3	
3C 249	A	10 59 24.40	-00 58 32.8	
	B	29.16	59 05.4	
	C	27.02	-01 00 21.5	
	D	28.74	00 19.5	
	E	29.08	01 08.5	
	F	27.98	00 53.9	
	H	24.63	00 57.9	
	I	23.46	01 20.9	
	J	21.86	00 36.8	
	K	22.86	-00 59 40.9	
	L	34.77	59 05.9	not shown
	M	34.38	-01 01 11.4	" "
3C 250	A	11 06 10.60	+25 15 41.6	
	B	07.34	18 05.1	
	C	05.76	17 58.1	
	E	05 59.94	23 20.1	
	F	06 19.65	19 58.0	
	G	24.25	15 25.3	
	H	21.86	13 52.2	
3C 255	A	11 16 46.16	-02 47 04.2	galaxy
	C	47.60	47 21.1	
	D	51.20	47 17.0	
	E	51.49	47 39.5	
	F	55.73	51 28.7	
	G	39.28	48 27.9	
	H	34.06	42 31.9	
	I	17 05.61	44 51.2	
3C 263.1	A	11 40 43.46	+22 23 20.2	defect?
	C	53.45	22 31.9	
	D	53.11	22 44.4	
	E	41 01.38	25 05.1	
	F	40 43.84	25 13.4	
	G	39.78	24 27.6	
3C 268.1	A	11 57 38.42	+73 18 10.7	
	B	55.64	18 17.5	
	C	44.45	17 09.8	
	D	15.13	18 43.8	
	E	56.10	17 40.1	galaxy
3C 268.3	A	12 03 58.21	+64 31 04.7	
	B	50.16	30 58.9	
	C	52.51	31 26.3	galaxy
	D	49.99	31 35.8	
	E	50.20	31 42.1	
	F	52.99	31 42.6	
	H	52.60	30 20.2	
	K	20.60	28 44.0	
	L	31.73	31 48.3	
	M	04 14.31	32 48.4	
	N	03 54.79	26 54.0	
3C 272	A	12 22 10.93	+42 24 17.3	
	B	21 58.92	23 24.4	
	C	21 53.98	23 45.1	
	D	21 51.53	23 18.2	
3C 275	A	12 39 43.60	-04 30 33.8	galaxy
	C	48.11	29 30.0	
	G	44.06	29 36.6	
	I	36.29	31 58.2	
	J	41.82	28 48.3	
	K	40.65	27 07.6	
	L	47.87	28 45.7	
	M	56.62	30 47.1	
	N	53.18	31 12.5	
3C 280	A	12 54 44.88	+47 35 55.8	
	B	47.78	35 58.9	
	C	42.53	35 14.6	
	D	39.05	37 23.0	
3C 289	A	13 43 27.36	+50 02 45.4	
	B	28.99	01 07.0	Wynd. id
	D	18.90	00 51.6	
	E	20.85	00 36.9	
3C 294	B	14 04 36.79	+34 26 05.7	galaxy
	D	33.20	25 38.2	
3C 297	A	14 14 37.32	-03 49 09.3	
	B	45.24	52 38.9	not shown
	C	15 08.84	47 04.3	" "
	D	14 50.63	45 53.6	
	E	43.66	48 15.6	
	F	49.42	49 14.7	galaxy
	G	49.55	48 52.7	
3C 299	D	14 19 03.61	+41 58 00.3	galaxy
	F	18.61	57 41.6	
	G	12.50	57 39.3	
	H	12.16	42 01 16.6	
	J	18 45.70	41 59 59.5	
	K	50.24	42 06 03.4	
3C 305.1	A	14 47 39.22	+77 08 35.4	
	B	43.74	38.7	
	C	47.53	53.3	
	F	48 00.37	03.8	
	Va	48 06.37	15.4	

TABLE 2 - continued

Field	Star	α 1950	ζ 1950	Remarks	Field	Star	α 1950	ζ 1950	Remarks	Field	Star	α 1950	ζ 1950	Remarks
3C 321	A	15 29 41.15	+24 15 00.3		3C 337	C	16 27 23.83	+44 25 33.0		3C 437	A	21 44 57.13	+15 06 13.8	
	C	41.93	15 00.6			D	21.75	26 33.5			B	55.70	06 20.1	
	D	33.75	14 37.1			E	14.54	26 44.8			C	56.56	06 16.0	
	E	47.15	15 28.2	galaxy		F	24.49	24 51.3			D	59.17	07 11.0	
	F	50.30	13 19.5			G	24.43	24 24.9			E	58.66	07 00.5	
						H	32.50	25 42.9			F	57.89	06 57.2	
3C 324	A	15 47 40.24	+21 34 27.3	galaxy		I	16.00	29 22.9			G	45 00.99	06 10.6	
	C	34.73	35 07.9			J	06.37	23 20.6			H	02.65	05 51.8	
	D	36.86	35 27.2								I	02.49	05 46.9	
	E	35.71	37 59.7		3C 352	A	17 09 09.70	+46 05 09.2			J	03.41	05 33.7	
	F	40.59	38 19.4			B	22.63	04 33.9			L	44 48.85	08 39.9	
	G	48.78	33 19.6			C	10.39	04 19.5			M	55.18	06 39.9	
						D	17.67	05 11.9						
3C 326.1	A	15 54 08.13	+20 11 15.5			E	24.04	04 07.5		3C 458	A	23 10 20.88	+05 00 27.5	
	B	07.14	13 22.1	galaxy		F	32.44	05 49.2			B	21.83	04 59 10.3	
	C	06.08	15 52.1			G	00.65	06 04.2			C	03.12	59 50.2	
	D	53 54.03	14 32.0			H	03 56.72	03 56.3			D	10.36	05 05 19.2	
	E	40.18	13 29.3								E	21.54	04 47.8	
	F	47.47	10 34.2		3C 356	A	17 23 14.30	+51 01 07.2	galaxy		F	26.63	02 55.9	
	G	54.27	09 55.2			B	07.77	01 36.7						
	H	54 04.37	10 12.0			C	01.76	01 13.6		3C 460	D	23 18 59.56	+23 32 03.0	
	I	53 49.40	14 41.2			D	22 59.43	00 33.0			E	57.95	32 09.9	
						F	57.18	02 17.2	galaxy		F	57.89	31 57.7	
3C 330	A	16 09 03.71	+66 04 48.9			G	23 00.74	04 13.5			G	57.84	31 49.0	
	B	01.76	05 19.3			H	20.07	03 16.2			H	57.86	31 39.1	
	C	09.72	05 06.8			I	13.68	50 57 53.0			I	53.25	32 08.8	
	D	11.95	08 03.7			J	22 54.62	58 12.9			J	56.32	32 09.2	
	E	54.30	06 00.7			K	23 00.53	51 01 25.3			K	19 00.57	31 42.9	
	F	32.26	04 00.4	galaxy							L	02.15	30 41.2	
	G	38.40	03 54.6		3C 418	Chart and Positions in Kristian and Sandage (1970).					M	05.35	29 48.5	
	H	17.03	02 29.3											
	J	11.74	03 21.3											
	K	34.17	05 57.6											
	L	08 40.93	05 14.4											

TABLE 3

Optical Positions of Suggested New Identifications

Object (3C)	Nature	α(1950)	rms	δ(1950)	rms	Comments
14.....	?	00^{h}33^{m}29^s.29	±0^s.044	+18°21′28″.8	±0.65	
19.....	G	00 38 13.80	±0.019	+32 53 39.7	±0.34	
36.....	Q?	01 15 03.22	±0.291	+45 20 42.4	±0.27	
42.....	?	01 25 42.67	±0.050	+28 47 30.4	±0.63	
49.....	G	01 38 28.41	±0.053	+13 38 19.9	±0.39	
54.....	G	(01 52 26.55)	±~0.1	(+43 31 19)	±2	
99.....	N or Q	03 58 33.28	±0.045	+00 28 10.6	±0.52	
114.....	Smudge	04 17 27.85	±0.056	+17 46 39.1	±0.04	
194*.....	G?	08 06 37.88	±0.1	+42 36 56	±1	Parker's id OK
225a.....	G	(09 39 24.7)	±0.5	+14 05 30	±5	
225b.....	G	(09 39 32.4)	±0.3	(+13 59 29)	±4	
268.1	Confused	...	...	...	...	
268.3	G, cl	12 03 54.28	±0.091	+64 30 18.6	±0.43	
272.....	G or Q	(12 21 59.7)	±0.5	(+42 23 03)	±3	
275.....	G, cl	12 39 45.16	±0.077	−04 29 53.9	±0.71	Distant cluster
280a.....	G	(12 54 41.7)	±0.1	(+47 36 32)	±2	
280b.....	G	(12 54 41.1)	±0.1	(+47 36 28)	±2	
297.....	G, cl	(14 14 46.0)	±0.3	(−03 46 30)	±2	
299.....	G	14 19 06.25	±0.015	+41 58 30.4	±0.91	
305.1	G?	(14 47 49)	±1	(+77 08 46)	±2	
321.....	Q?	(15 29 40.3)	±0.5	(+24 12 54)	±4	
324.....	G, cl	(15 47 37.3)	±0.1	(+21 34 42)	±2	
330†.....	G, cl	Galaxies between double radio source				
337‡.....	G, cl	Galaxies between double radio source				
352.....	G	(17 09 18.0)	±0.1	(+46 05 06)	±1	
418.....	?	(20 37 7.3)	±0.1	(+51 08 35)	±1	
458.....	G	(23 10 21.9)	±0.5	(+05 00 26)	±2	
460.....	G	23 18 59.67	±0.085	+23 30 20.7	±0.42	

NOTE.—Coordinates in parentheses were estimated on prints, not measured with the engine.

* Véron's position in Wlerick *et al.* (1971) is listed.

† The double radio positions are 16^{h}09^{m}09^s.3, 16^{h}09^{m}17^s.9; and +66°04′09″.1, +66°04′36″.0 (1950).

‡ The double radio positions are 16^{h}27^{m}16^s.5, 16^{h}27^{m}20^s.1; and +44°25′45″, +44°25′37″ (1950).

TABLE 4

PHOTOMETRY OF SOMETIME CANDIDATES NEAR RADIO POSITIONS NOT NOW CONSIDERED AS IDENTIFICATIONS

Source	Star	α(1950)	δ(1950)	V	$B-V$	$U-B$	Remarks or Chart
3C 36.....	A	$01^h15^m02^s.58$	+45°20′31″.6	18.89	0.83	0.44	Wyndham (1966)
3C 68.2.....	E	02 31 18.78	+31 20 54.7	17.59	0.87	0.44	Véron "*a*"
	F	19.45	20 22.5	18.56	0.86	0.10	
	G			15.32	0.69	0.07	Wyndham
3C 107.....	H	04 09 50.20	−01 06 50.4	17.04	0.62	0.04	Wyndham
3C 172.....	A	06 59 02.47	+25 17 21.2	18.9	1.03	0.21	
	L			16.05	0.57	0.00	Wyndham
3C 175.1.....	M	07 11 13.17	+14 41 10.0	13.47	1.03	0.82	
	N	14.37	41 29.9	17.01	0.54	0.07	Wyndham
	P	(13.6	41 50)	16.63	0.96	0.65	Bolton's position
3C 289.....	B	13 43 28.99	+50 01 07.0	17.28	0.64	0.05	Wyndham
3C 294.....	D	14 04 33.20	+34 25 38.2	12.02	0.86	0.44	Wyndham (1966)
	E			17.41	0.60	−0.25	
3C 352.....	D	17 09 17.67	+46 05 11.9	16.16	0.64	0.05	
3C 356.....	N	(17 23 06.96	+50 59 59.9)	14.92	0.73	0.32	Wyndham's identification
	M			17.98	0.44	−0.07	
3C 437.....	G	21 45 00.99	+15 06 10.6	17.42	0.74	0.13	

parentheses (table 3) were estimated from the 200-inch plates via the overlay process described in § II. Their accuracy is of order 1–2″, which should be adequate for identifications.

At the time (1965 and earlier) when radio-source positions were generally no more accurate than ∼15″, identifications were often attempted on the basis of peculiar colors. Photoelectric photometry had been obtained in such early efforts for 10 of the present fields to test sometime candidates, and the results are listed in table 4. Again, the coordinates are accurate to the rms mean of ∼0″.6 for those listed without parentheses, and are good to ⩽2″ for the others. The photometry was done with the Hale 5-m telescope in the course of other fainter survey work between 1963 and 1966. The photometric errors are typically ±0.02 mag, and the stars are identified in figures 1–9. None of the objects in table 4 are identifications of the radio sources.

IV. GALAXIES IN CLUSTERS

One of the objectives of the work was to locate distant radio galaxies in clusters to provide high-redshift candidates for the Hubble diagram. Of the 26 definite or probable identifications, 10 are galaxies that are likely to be in clusters or groups. Most of these are fainter than the routine *Sky Survey* limit, and hence are fainter in apparent magnitude than 3C 295 at $z = 0.461$.

Because apparent magnitude is a good indicator of distance due to the narrow optical luminosity function for radio galaxies (Sandage 1972, fig. 3), there is every reason to believe that these identified brightest members of groups will have large redshifts.

The sources identified as galaxies in clusters or groups are 3C 19, 268.3, 275, 280, 297, 299, 324, 330, 337, and 356. The best cases are 3C 268.3, 3C 299, 3C 324, 3C 330, and 3C 337. No spectroscopy or photometry has yet been obtained, except for 3C 299 where Spinrad and Smith (1973) have measured a redshift of $z = 0.367$, and for 3C 460 where our preliminary result of $z = 0.27 \pm 0.02$ is discussed in the notes to table 1.

V. POSSIBLE QUASARS

Identification of radio quasars with a blind eye to color is important in the search for an intrinsic cutoff in quasar redshifts (cf. Sandage 1972). Current data suggest that this may occur for z as low as about 3. The reality of such an effect would be fundamental for cosmology, but it is well known that current quasar-candidate lists may be biased against inclusion of larger redshifts because of color discrimination caused by some of the earlier identification methods, and therefore that the current apparent cutoff may be illusory. Identification of radio quasars by means of position coincidence alone clearly avoids this bias.

The classification of the objects newly identified here as compact galaxies (N systems), quasars, or even very distant normal E galaxies, is difficult because of their faintness. Nevertheless, the only objects of the 26 that appear unresolved, and hence are candidates for quasars, are 3C 36, 3C 272, 3C 321, and 418. Our plate material is not good enough in other cases to decide definitely between intrinsically soft images or softness due to poor seeing. The objects identified as 3C 14, and even possibly 3C 297, might also be quasars. Most of the other objects marked G in table 1 have clearly soft or extended images.

The very small number of quasar candidates is surprising in view of their frequency of ∼20 percent of the brighter identified sources. Our plate material is not adequate (poor seeing) to determine the nature of some of the identifications, but there are so many definite galaxies in the sample that the scarcity of faint quasars here was unexpected. The number of objects, however, is too small for reliable statistics, and the reality of the effect can be tested only when a larger sample is available.

VI. PREVIOUS MISIDENTIFICATIONS AND MISINTERPRETATIONS

The increased accuracy of radio positions requires reexamination of identifications that were previously suggested when the best radio positions had errors of $\sim 20''$. The most extensive and valuable summary, still used, is that of Wyndham (1966). Many of Wyndham's identifications have subsequently been confirmed by spectra, especially for quasars, but some have not. For convenience we list here those source positions where we do not confirm the object marked on Wyndham's finding charts. That the list is so small is a tribute to the extensive efforts of Wyndham, Véron, the Cambridge group, and many others since 1964.

We do not confirm the marked objects on the charts of 3C 36 (Véron 1966*b*), or of 3C 68.2, 99, 114, 124, 175.1, 210, 228, 263.1, 289, and 3C 356 of Wyndham (1966) for the reasons listed in the notes to table 1.

Finally, it may be of interest to comment on the suggestion of Wlerick and Véron (1967) concerning the identification of seven 3CR sources with galactic stars. The radio positions were then known to an accuracy of only $\sim 10''$, and the identifications could not be secure for that reason alone. Our present sample contains four of the seven sources (3C 289, 294, 352, and 356). The first two fields are empty on the basis of radio positions, which now differ from the optical positions of the stars by $\sim 43\ \sigma$ for 3C 289 and $\sim 10\ \sigma$ for 3C 294. Further, 3C 352 is now identified, and 3C 356 is $\sim 10''$ from any optical object. We have no new data on the other three candidates.

Many people have helped in this work. We gratefully acknowledge preprints and reprints of radio positions from the Royal Radar Establishment (Adgie, Crowther, and Gent), from Mullard Radio Observatory, from Green Bank (Wade), and from Jodrell Bank (I. W. A. Browne). We are particularly indebted to R. L. Adgie for pointing out an error in the original manuscript. Information exchange on optical objects with P. Véron, H. Spinrad, and M. Longair is also appreciated. Several plates were taken by others, and we wish to thank P. Véron, W. Miller, and R. Brucato for them. As always, it is a pleasure to thank John Bedke in the photo lab for the large amount of excellent work required to make the finding charts from the original plates and Felice Woodworth for the tedious job of lettering them. It is a pleasure to thank the night assistants on Palomar—Dennis Palm at the 48-inch; Gary Tuton and Juan Carrasco at the 200-inch—for their cheerful help in obtaining the plate material. Finally, the calculating equipment given by F. L. Moseley to the Observatories was extremely useful in this work, and we are grateful to him for it.

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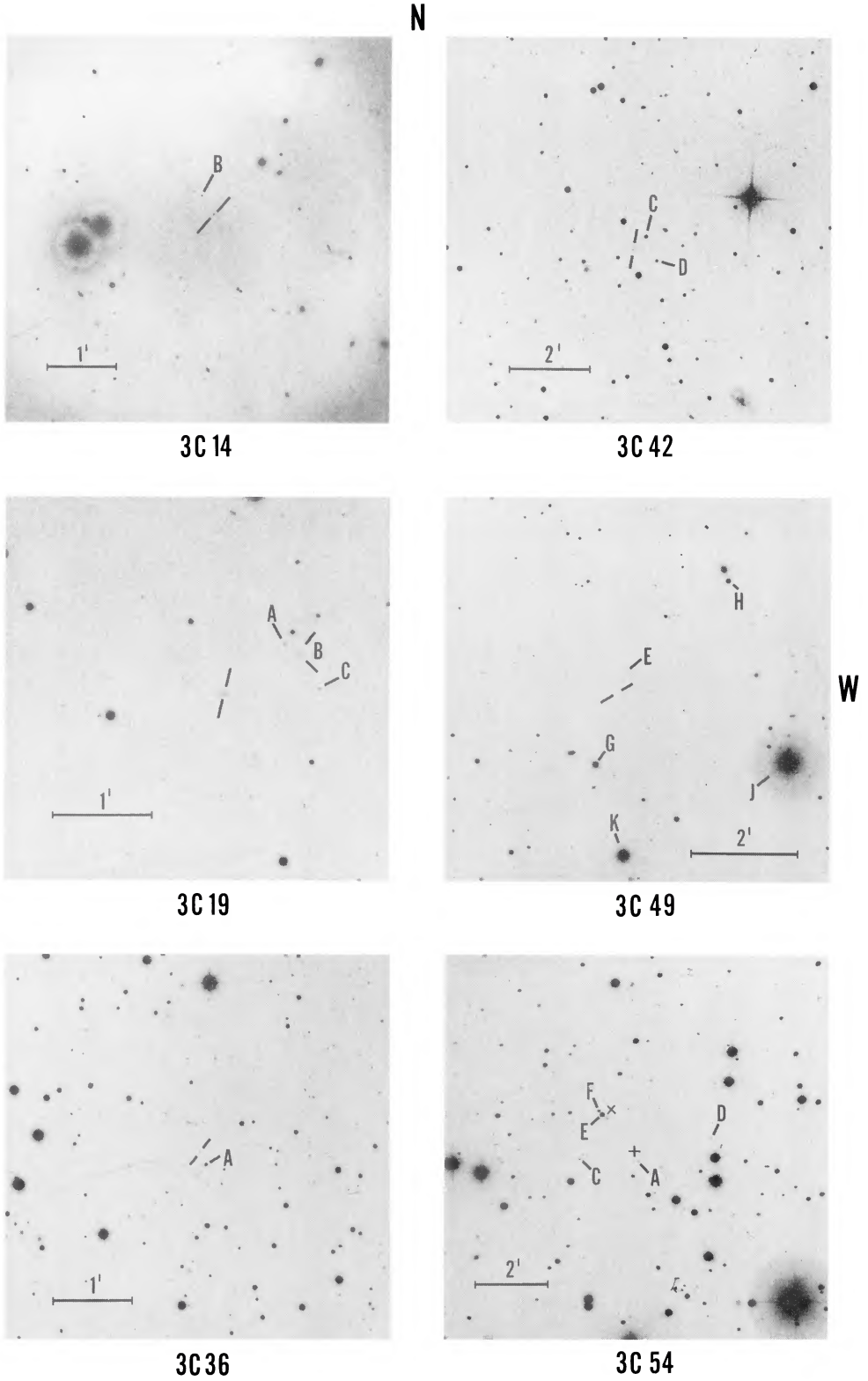

FIG. 1.—Finding charts for the fields in table 1. The telescope and plate combinations, in an obvious notation, are: 3C 14 (200 *R*, IT); 3C 19 (200 *R*); 3C 36 (200 *R*); 3C 42 (48 IIIaJ); 3C 49 (200 *V*); 3C 54 (200 *V*).

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PLATE 2

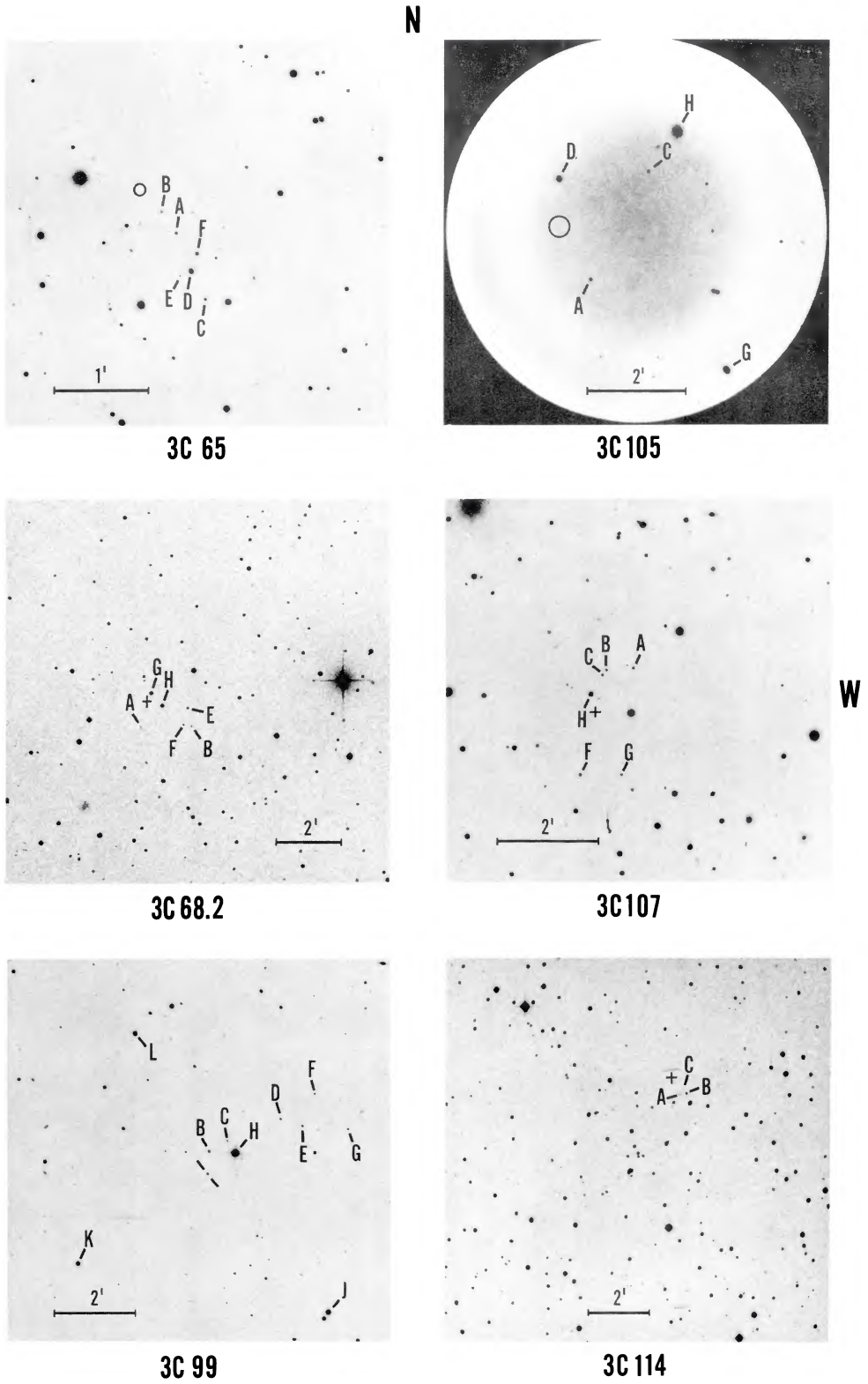

FIG. 2.—Finding charts for 3C 65 (200 *R*); 3C 68.2 (48aO); 3C 99 (200 *R*); 3C 105 (200 *R*, IT); 3C 107 (200 *V*); 3C 114 (48 IIIaJ).

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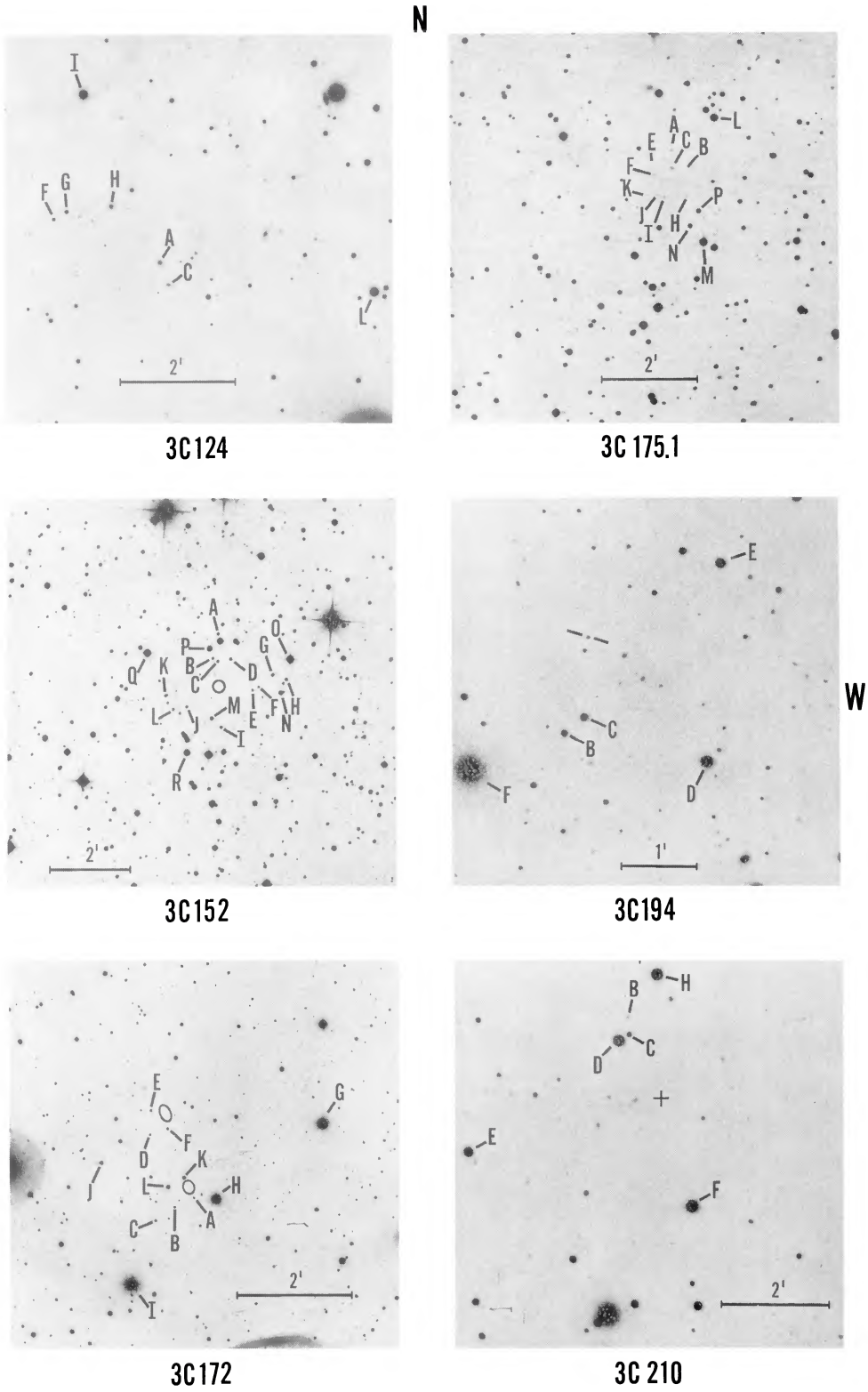

FIG. 3.—Finding charts for 3C 124 (200 *R*); 3C 152 (48 IIIaJ); 3C 172 (200 *V*); 3C 175.1 (48 IIIaJ); 3C 194 (200 *V*); 3C 210 (200 *V*).

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PLATE 4

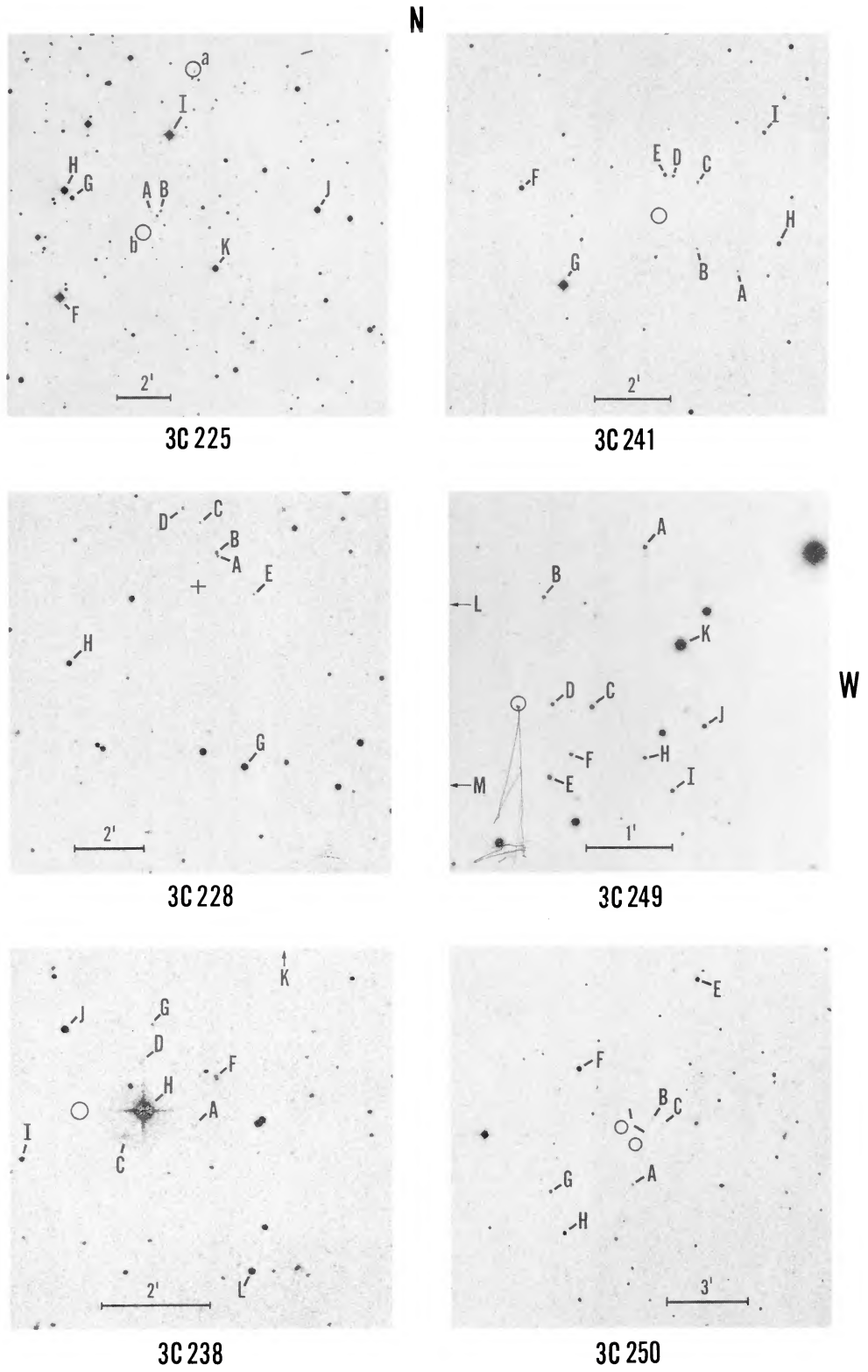

FIG. 4.—Finding charts for 3C 225 (48 IIIaJ); 3C 228 (48aO); 3C 238 (48 aD); 3C 241 (48 aD); 3C 249 (200 *V*); 3C 250 (48 aO).

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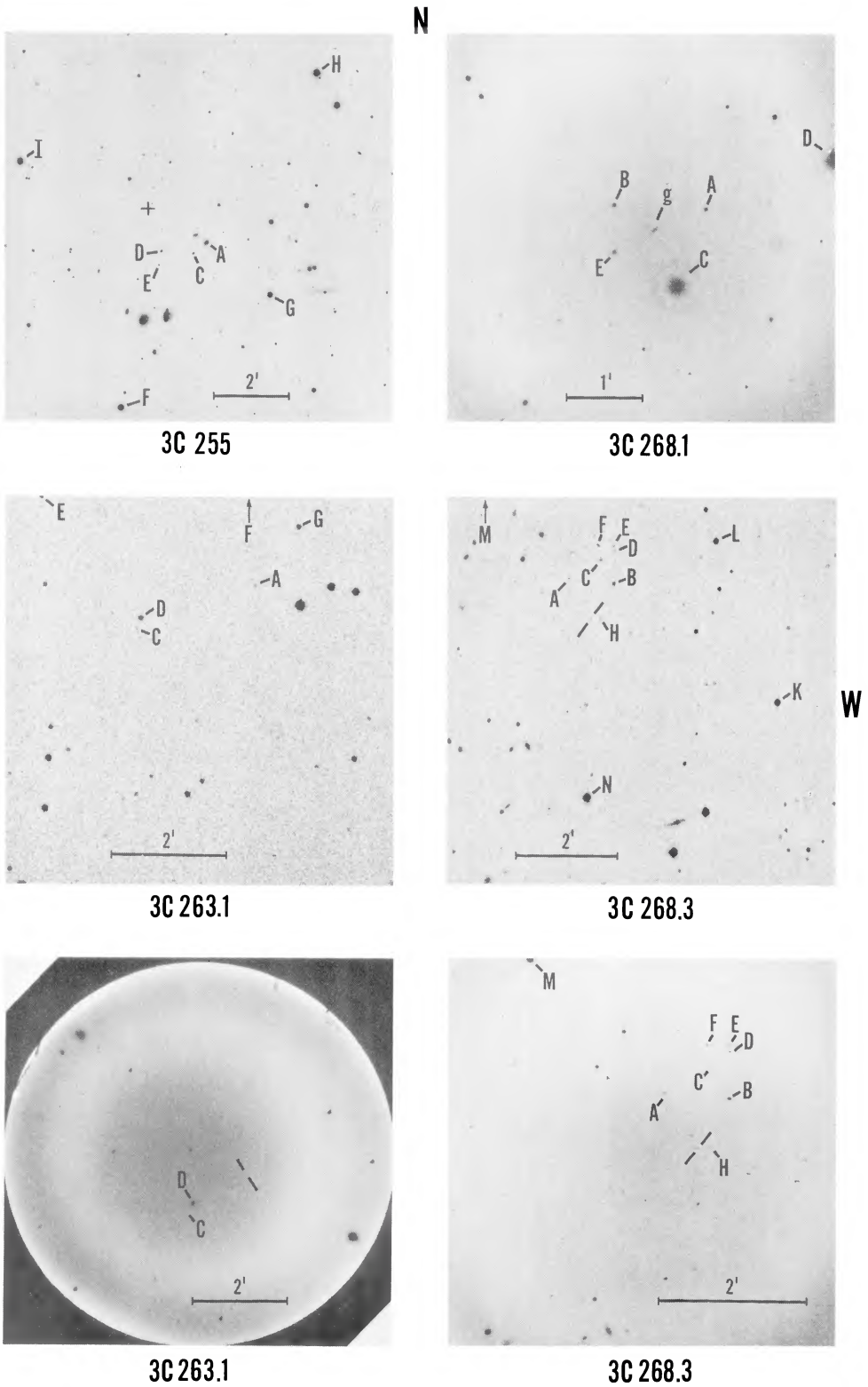

FIG. 5.—Finding charts for 3C 255 (200 *V*); 3C 263.1 (48 aO); 3C 263.1 (200 *R*, IT); 3C 268.1 (200 *R*, IT); 3C 268.3 (48 IIIaJ); 3C 268.3 (200 *R*, IT).

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PLATE 6

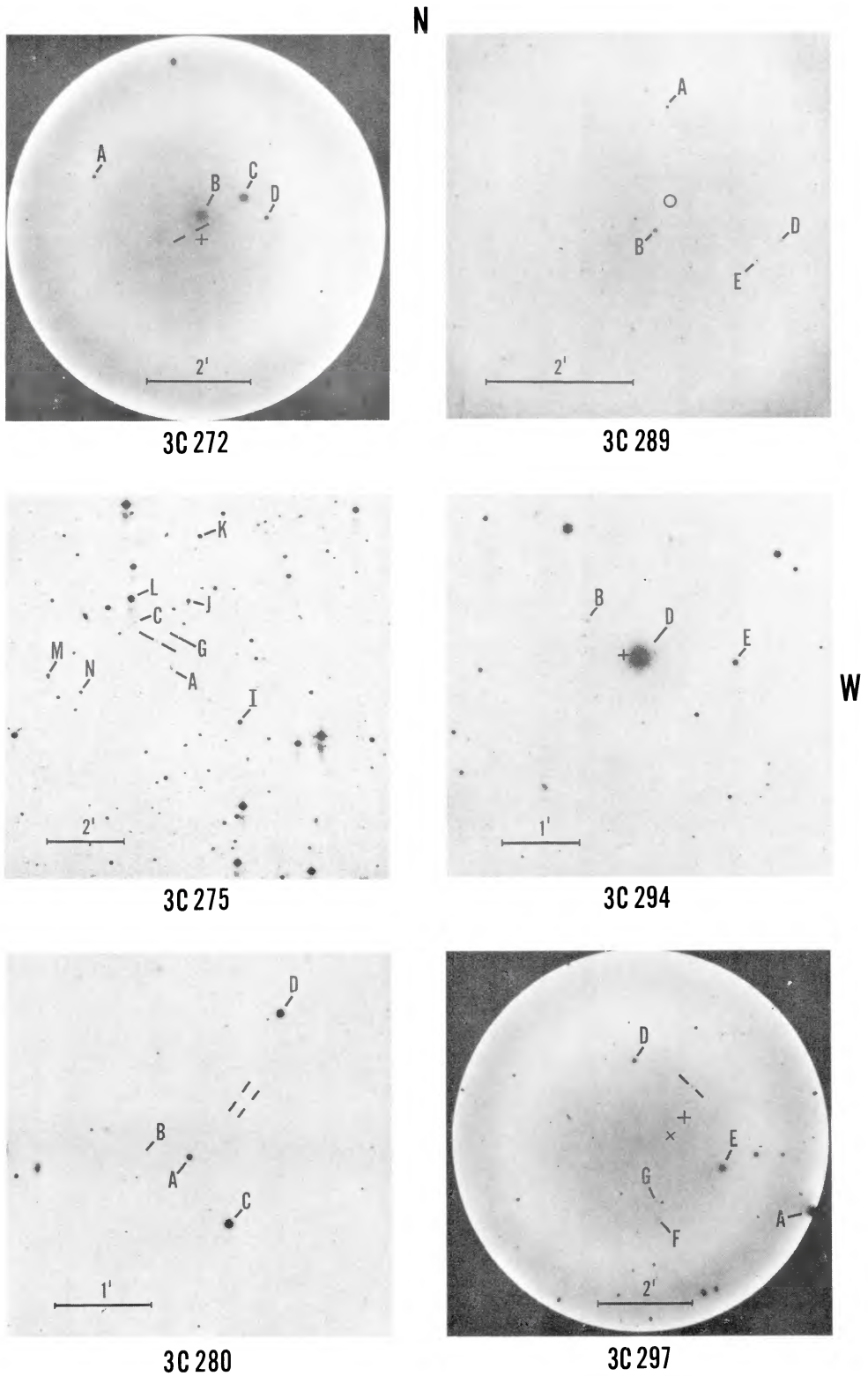

FIG. 6.—Finding charts for 3C 272 (200 *R*, IT); 3C 275 (48 IIIaJ); 3C 280 (200 *V*); 3C 289 (200 *R*, IT); 3C 294 (200 *V*); 3C 297 (200, *R*, IT).

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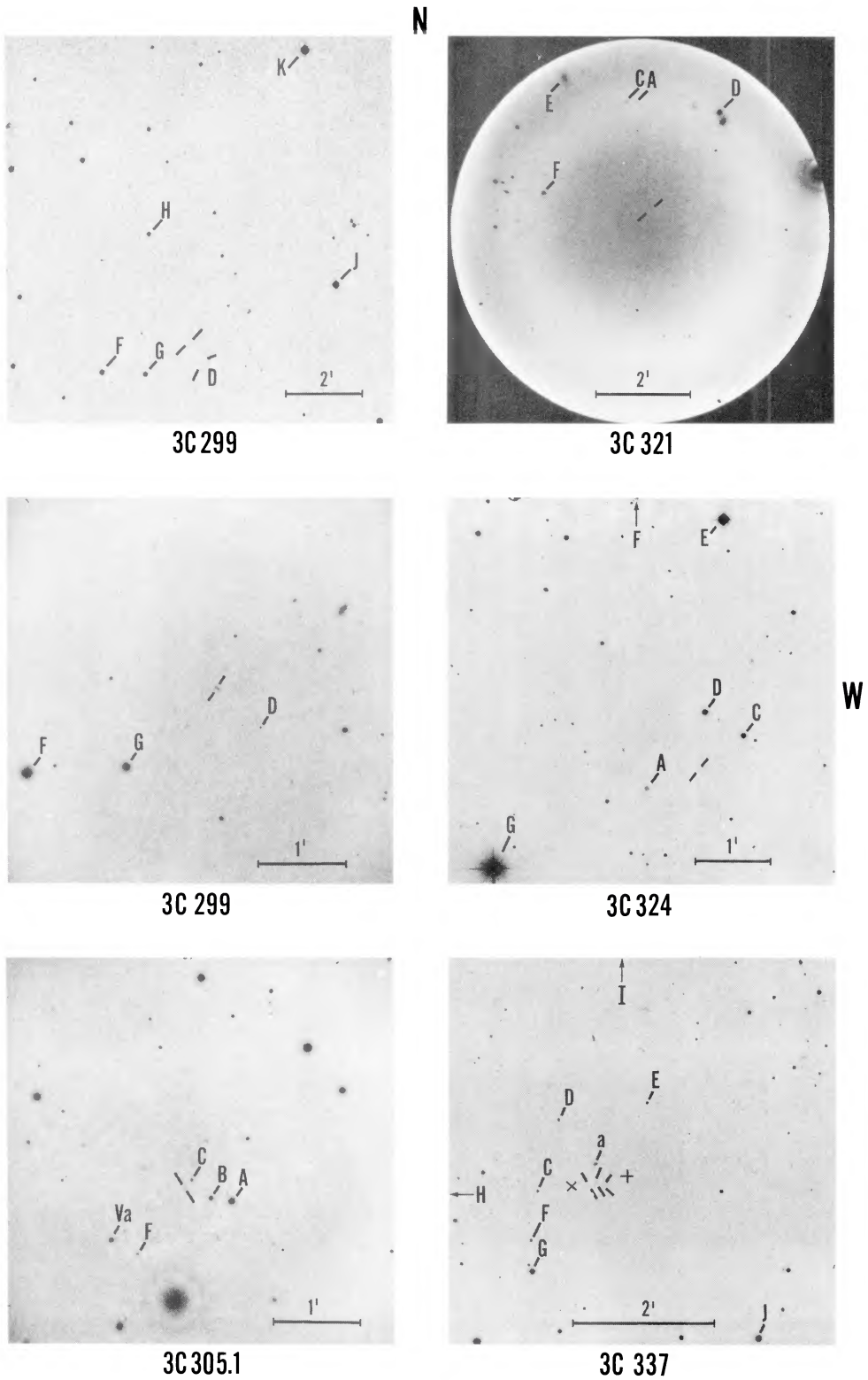

FIG. 7.—Finding charts for 3C 299 (48 aO); 3C 299 (200 *R*, IT); 3C 305.1 (200 *R*, IT); 3C 321 (200 *R*, IT); 3C 324 (200 *V*); 3C 337 (200 *V*).

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PLATE 8

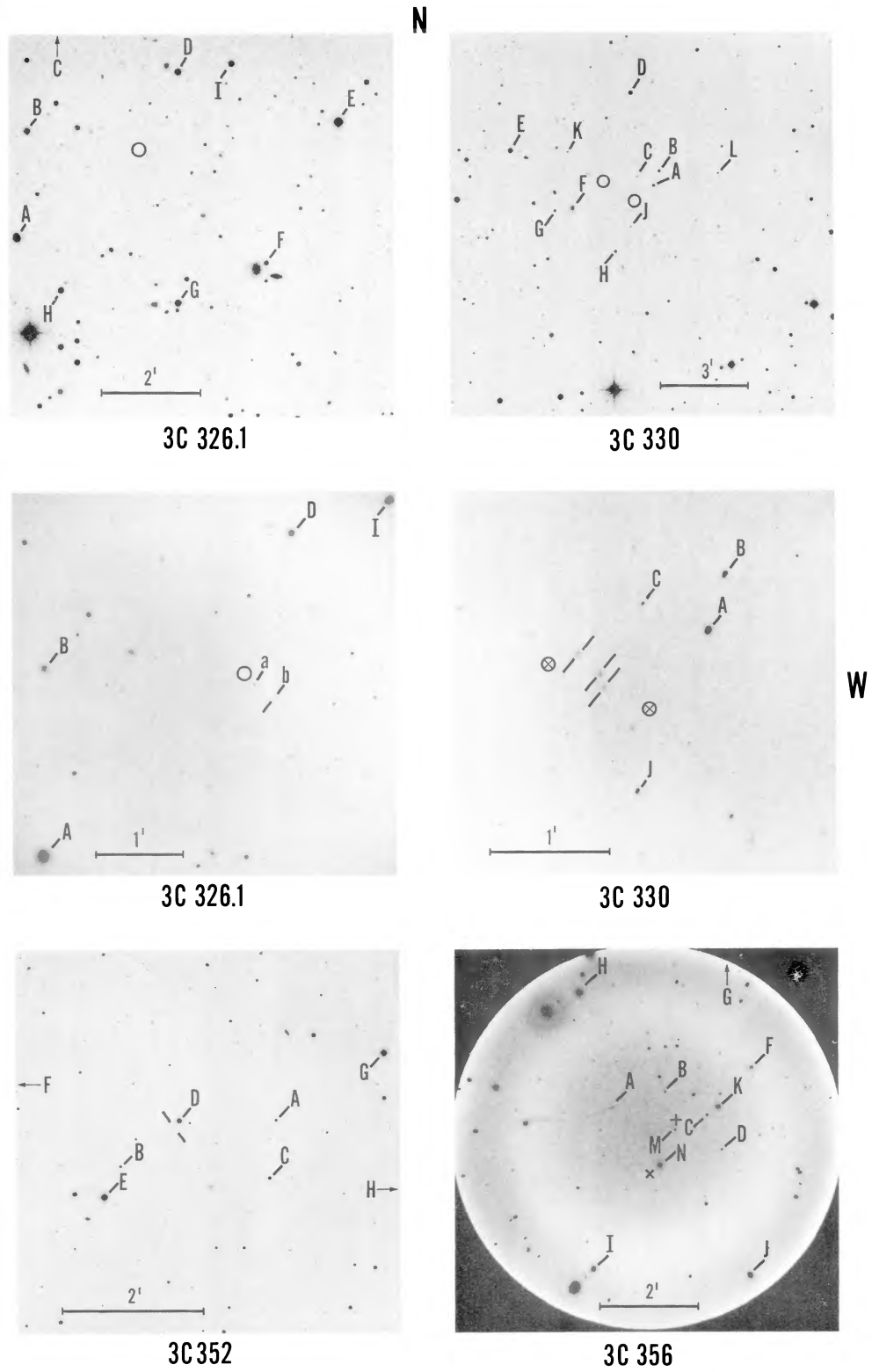

FIG. 8.—Finding charts for 3C 326.1 (48 IIIaJ); 3C 326.1 (200 *R*, IT); 3C 352 (200 *V*); 3C 330 (48 aD); 3C 330 (200 *R*, IT); 3C 356 (200 *R*, IT).

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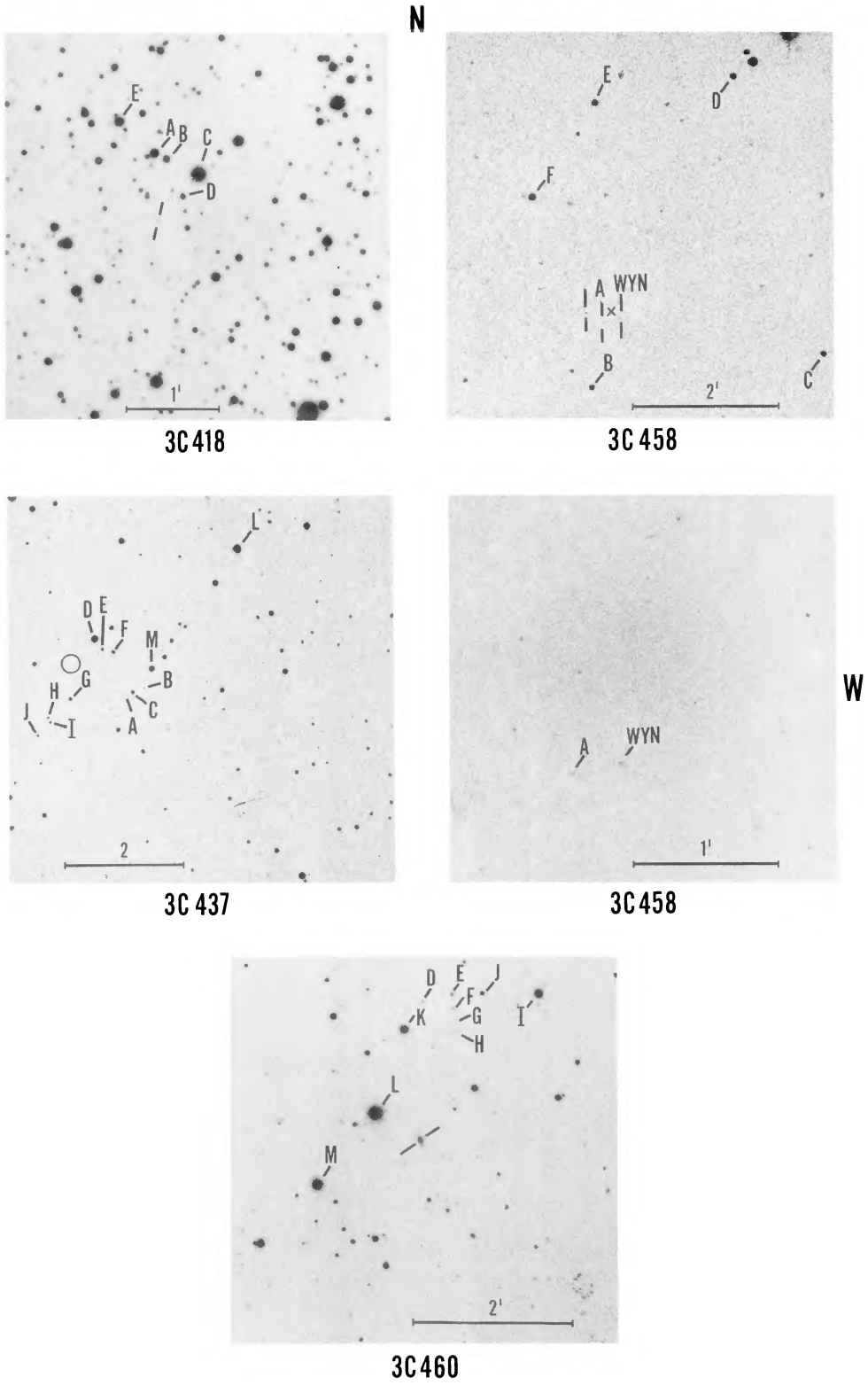

FIG. 9.—Finding charts for 3C 418 (200 *R*); 3C 437 (48 IIIaJ); 3C 458 (48 aD); 3C 458 (200 *R*, IT); 3C 460 (200 *R*)

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