Lists of accepted and proposed gravitational lens systems

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Abstract: Lists and color illustrations of accepted and proposed cases of multiply imaged sources, radio rings, giant luminous arcs and arclets are presented.

In this paper, we have compiled lists of presently accepted cases of multiply imaged sources (quasars, AGNs, radio galaxies, etc.; see Table 1), of additional proposed cases (Table 2), of radio rings (Table 3) and of giant luminous arcs and arclets (Table 4).

The criteria used for the acceptance of a gravitational lens (GL) in Tables 1, 3 or 4 are essentially those explicited by Peter Schneider in his concluding remarks to LIAC93 (i.e. 1993 Liège International Astrophysical Colloquium, see these proceedings). A detailed description of the observational status of each GL candidate listed in Tables 1-4 may be found in [REF93.2]. We refer the reader to the "Non exhaustive bibliography on gravitational lensing" appearing at the end of these proceedings (Pospieszalska-Surdej, Surdej and Véron) for exact information on the discovery paper(s) of each individual GL. It is our intention to keep updated these tables and to make them available (via FTP) to anyone interested. Please, keep us informed in the future of any necessary change, update, etc. to be brought to these tables (our contact addresses may be found in the list of participants to LIAC93).

Color illustrations of some of the best known (accepted or proposed) GL systems are shown in Figures 1, 2 (multiply imaged quasars, radio sources, mini arcs and rings) and 3 (giant luminous arcs and arclets). The various types of image configurations observed among the known GL systems may be compared with those produced in the optical gravitational lens experiment (see Surdej, Refsdal and Pospieszalska-Surdej, in these proceedings).

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Acknowledgements

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Table 1: Presently accepted cases of multiply imaged sources

Source name (QSO/AGN)	Number of images	Image brightness/ Abs. Mag.	Separation/ Time delay [est.] or (meas.)	z_s	Lens type	Lens brightness	z_l	$M_l(M_\odot)$/ Radius/ Mic. lens	Detection (O/R)	Reference
0957+561 A-B (QSO)	2	B=17.5 (A) B=17.7 (B) $M_B = -27.8$	6.1"(A-B) 1.14? yr (meas.)	1.41	G/Cs	R=18.5	0.36 0.5	1.1(12) 3.1" ML	O/R	Walsh et al. 1979 [WAL79.1]
PG 1115+080 A1/2-C (QSO)	4 5?	B=17.2 (A1) B=17.2 (A2) B=18.7 (B) B=18.2 (C) $M_B = -29.0$	0.5"(A1-2) 1.8"(A-B) 2.3"(A-C) days,months	1.72	G	R=19.8	0.29	ML	O	Weymann et al. 1980 [WEY80.1]
MG 2016+112 A-C' (AGN)	3	i=22.9 (A) i=23.2 (B) i=24 (C')	3.4"(A-B) 3.8"(A-C') 0.5-1 yr	3.27	2Gs	i=21.9	1.01? $\geq$ 2?	ML?	R/O	Lawrence et al. 1984 [LAW84.1]
2237+0305 A-D (QSO)	4	r=17.6 (A) r=17.8 (B) r=18.1 (C) r=18.4 (D) $M_r = -28.7$	1.8"(A-B) 1.4"(A-C) 1.7"(A-D) days	1.69	G	r=14.5	0.04	2.0(10) 0.9" ML	O	Huchra et al. 1985 [HUC85.1]
UM 673 A-B (=0142-100) (QSO)	2	B=17.0 (A) B=19.1 (B) $M_B = -29.0$	2.2"(A-B) $\simeq$ 7 weeks	2.72	G	R=19.0	0.49	2.4(11) 1.1"	O	Surdej et al. 1987 [SUR87.1]

Table 1 (cont.): Presently accepted cases of multiply imaged sources

Source name (QSO/AGN)	Number of images	Image brightness/ Abs. Mag.	Separation/ Time delay [est.] or (meas.)	z_s	Lens type	Lens brightness	z_l	$M_l(M_\odot)$/ Radius/ Mic. lens	Detection (O/R)	Reference
H 1413+117 A-D (QSO)	4	R=18.3 (A) R=18.5 (B) R=18.6 (C) R=18.7 (D) $M_R = -28.7$	0.8"(A-B) 0.9"(A-C) 1.1"(A-D) $\leq$ 1 month	2.55	G?		1.4? 1.7?	5.0(11) ML?	O/R	Magain et al. 1988 [MAG88.1]
MG 0414+0534 A-D (Radio Galaxy)	4	R=23 (A-D)	3"(A-D)	2.63?	G?	R=22.4	1.0?		R/O	Hewitt et al. 1989 [BOOK89.1]
B 1422+231 A-D (QSO)	4	R=16.5 (A-D) $M_R = -29.5$	1.3"(A-C)	3.62	G?		0.64?		R/O	Patnaik et al. 1992a [PAT92.2]
B 1938+666 A-D (Radio Galaxy?)	4+ mini-arc	r=23 (A-D)	$\leq$ 1.0"						R/O?	Patnaik et al. 1993 [PAT93.1]
MG 0751+2716 A-D (Extended radio source)	4+ structure+ mini-arc		$\leq$ 1.0"		G	V=19			R	Lehár et al. 1993a [LEH93.2]

Table 2: Additional proposed cases of multiply imaged sources

Source name (QSO/AGN)	Number of images	Image brightness/ Abs. Mag.	Separation/ Time delay [est.] or (meas.)	z_s	Lens type	Lens brightness	z_l	$M_l(M_\odot)$/ Radius/ Mic. lens	Detection (O/R)	Reference
2345+007 A-B (QSO)	2	B=19.5 (A) B=20.1 (B) $M_B = -26.4$	7.3"(A-B)	2.15		J>25.5		ML?	O	Weedman et al. 1982 [WEE82.1]
1634+267 A-B (QSO)	2	B=19.2 (A) B=20.8 (B) $M_B = -26.4$	3.8"(A-B)	1.96	G?	R=20.0?	0.57?	1.0(12)?	O	Djorgovski and Spinrad 1984 [DJO84.1]
3C 324 A-C (AGN)	3	R=22.7 (A) R=23.3 (B)	2"(A-B)	1.206	G	R=22.5	0.84	1.0(12)	R/O	Le Fèvre et al. 1987 [LE 87.1]
MG 0023+171 AB-C (AGN)	2	r=22.8 (AB) r=23.4 (C)	4.8"(AB-C)	0.95					R/O	Hewitt et al. 1987 [HEW87.1]
3C 194 (AGN)	2	R=21.5	3.5"	1.18	G	R=19.0	0.31	1.0(12)	R/O	Le Fèvre and Hammer 1988 [LE 88.1]
1429-008 A-B (QSO)	2	R=17.7 (A) R=20.8 (B) $M_R = -27.9$	5.1"(A-B)	2.08			1.6?		O	Hewett et al. 1989 [HEW89.1]

Table 2 (cont.): Additional proposed cases of multiply imaged sources

Source name (QSO/AGN)	Number of images	Image brightness/ Abs. Mag.	Separation/ Time delay [est.] or (meas.)	z_s	Lens type	Lens brightness	z_l	$M_l(M_\odot)$/ Radius/ Mic. lens	Detection (O/R)	Reference
UM 425 A-B (=1120+019) (QSO)	2	V=16.2 (A) V=20.8 (B) $M_V = -28.6$	6.5"(A-B)	1.46	G? C?	R=22.5	0.6?		O	Meylan and Djorgovski 1989 [MEY89.1]
3C 297 (AGN)	2	R=21.0	2.4"	1.4	G				R/O	Hammer and Le Fèvre 1990 [HAM90.2]
1208+1011 A-B (QSO)	2	V=18.1 (A) V=19.7 (B) $M_V = -28.2$	0.47"(A-B)	3.80					O	Magain et al. 1992 [MAG92.1]
BRI 0952-01 A-B (QSO)	2	ΔI=1.35 (A/B)	0.9"(A-B)	4.5					O	McMahon et al. 1992 [MCM92.1]
HE 1104-1805 A-B (QSO)	2	B=16.2 (A) B=18.0 (B) $M_B = -29.4$	3"(A-B)	2.303			1.66?		O	Wisotzki et al. 1993 [WIS93.1]
1009-025 A-B (QSO)	2	R=17.6 (A) R=20.0 (B) $M_R = -28.5$	1.55"(A-B)	2.74	G?		1.62?		O	Surdej et al. 1993 [BOOK93.1]

Table 3: Radio rings

Source name	Number of images	Source type	Separation/ Diameter	z_s	Lens type	Lens brightness	z_l	$M_l(M_\odot)$/ Radius	Detection (O/R)	Reference
MG 1131+0456 A-B	2+ring	radio lobe	2.1"(diam.)	1.13?	G	R=22	0.85?		R/O	Hewitt et al. 1988 [HEW88.1]
MG 1654+1346	ring	radio lobe	2.1"(diam.)	1.74	G	r=18.7	0.25	3.0(11) 1.1"	R/O	Langston et al. 1989 [LAN89.1]
PKS 1830-211	2+ring	radio jet	1.0"			$V \simeq 23.0$			R	Rao and Subrahmanyan 1988 [RAO88.1] Jauncey et al. 1991 [JAU91.1]
MG 1549+3047	ring	radio lobe	2.0"(diam.)	≥ 0.3?	G	V=16	0.111		R/O	Lehár et al. 1993b [LEH93.1]
B 0218+357 A-B	2+ring	radio lobe	0.33"(diam.)	0.94?	G	$r \simeq 20.0$	0.68		R/O	Patnaik et al. 1993b [PAT93.2]

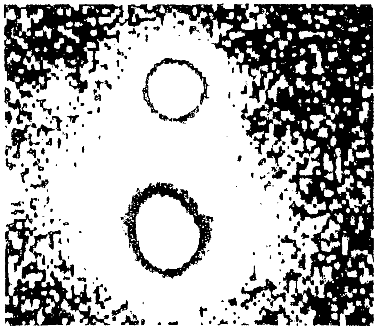
Explanations: [est.] or (meas.) ... estimated [default] or measured time delay, G (galaxy), C (cluster), ML (micro-lensing), R/O (radio and/or optical detection). All absolute magnitudes are calculated using $H_o = 50$ km/s/Mpc, $q_o = 0.5$ and an optical spectral index $\alpha = 0.7$.

Table 4: Giant luminous arcs and arclets

Cluster name	Arc magnitude	z_s	z_l	Reference
Abell 370	R=19.4 R=22.3	0.725 1.3?	0.374	Soucail et al. 1987, 1988 Lynds and Petrosian 1989 [SOU87.1, 88.2, LYN89.1]
Cl 2244-02	R=20.4	2.237	0.336	Lynds and Petrosian 1989 Mellier et al. 1991 [LYN89.1, MEL91.1]
Abell 963	R=23.1	0.771	0.206	Lavery and Henry 1988 [LAV88.1]
Cl 0024+1654	R=22.3	1.39?	0.391	Koo 1987 [KOO87.1] Mellier et al. 1991 [MEL91.1]
Cl 0500-24	R=19.8	0.91?	0.316	Giraud 1988 [GIR88.1]
Abell 2218	r=21.4 r=21.7	0.702 1.034	0.176	Pello-Descayre et al. 1988 Pello et al. 1992 [PEL88.1, 92.1]
Abell 1689				Tyson et al. 1990 [TYS90.2]
Cl 1409+52				Tyson et al. 1990 [TYS90.2]
Abell 2390	R=20.0	0.913	0.231	Pello et al. 1991 [PEL91.1]
AC 114				Smail et al. 1991 [SMA91.1]
Abell 2163	R=21.2, 21.8	0.728, 0.742	0.203	Soucail et al. 1994 [SOU94.1]
Abell 1942			0.23	Smail et al. 1991 [SMA91.1]
Abell 222			0.213	Smail et al. 1991 [SMA91.1]

Table 4 (cont.): Giant luminous arcs and arclets

Cluster name	Arc magnitude	z_s	z_l	Reference
Abell 2397				Smail et al. 1991 [SMA91.1]
MS 2137-23	R=21.6 B=23.3		0.32	Fort et al. 1992 [FOR92.1] Mellier et al. 1993 [MEL93.2]
Cl 0302+1658	R=22.4, 22.6		0.42	Mathez et al. 1992 [MAT92.2]
MS 1621.5+2640	V=23.9		0.426	Luppino and Gioia 1992 [LUP92.1]
MS 2053.7-0449	V=22.9		0.583	Luppino and Gioia 1992 [LUP92.1]
CL 2236-04	R=19.1	1.116	0.56	Melnick et al. 1993 [MEL93.1]
0957+561	R=23.5, 23.7		0.5 0.36	Bernstein et al. 1993 [BER93.1]
MS 0440+0204	B=22.9, 23.0 B=24.0		0.19	Luppino et al. 1993 [LUP93.1]
MS 1006+1202	V=22.2, 21.9 V=20.0, 22.3		0.221	Le Fèvre et al. 1993 [LE 93.1]
MS 1008-1224	V=21.53, 22.9		0.301	Le Fèvre et al. 1993 [LE 93.1]
MS 1455+2232	R=22.9		0.259	Le Fèvre et al. 1993 [LE 93.1]
MS 1910+6736	R=20.6		0.246	Le Fèvre et al. 1993 [LE 93.1]
GHO 2154+0508		0.721	0.32	Lavery et al. 1993 [LAV93.1]



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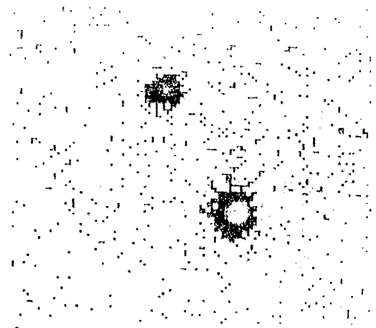

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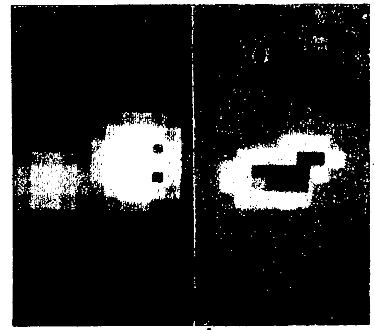

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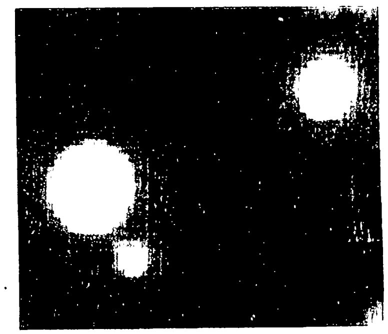
Fig.	Source name	Image(s)	Waveband/Telescope	Courtesy of
a	0957+561	A-B + Lens	Optical R / CFH	Dr. C. Vanderriest
b	2345+007	A-B	Optical R / CFH	Dr. C. Vanderriest
c	UM 673 (0142-100)	A-B	Optical R / ESO-MPI 2.2m	Liège Group
d	UM 673 (0142-100)	Lens	Optical R / ESO-MPI 2.2m	Liège Group
e	1208+1011	A-B	Optical R / NOT	Dr. J. Hjorth
f	HE 1104-1805	A-B	Optical R / NTT	Dr. D. Reimers
g	1009-025	A-B	Optical R / NTT	Liège Group
h	BRI 0952-01	A-B	Optical I / CFH	Dr. R. McMahon
i	PG 1115+080	A-D	Optical R / CFH	Dr. G. Lelièvre
j	MG 2016+112	A-C' + Lens	Optical R / NTT	Dr. C. Vanderriest
k	2237+0305	A-D + Lens	Optical R / CFH	Dr. G. Lelièvre



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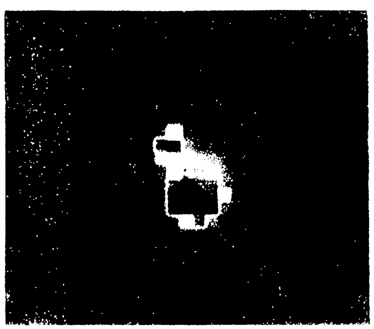

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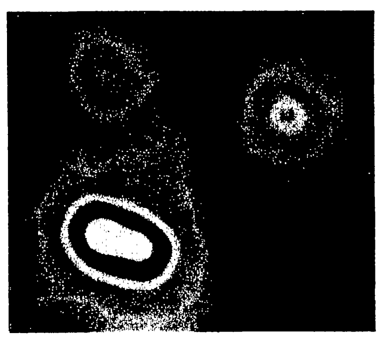

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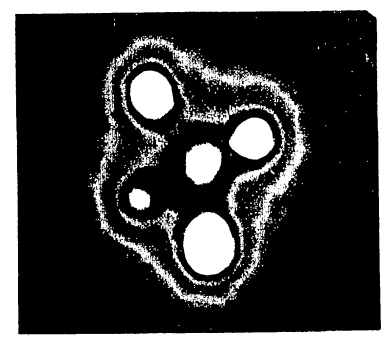

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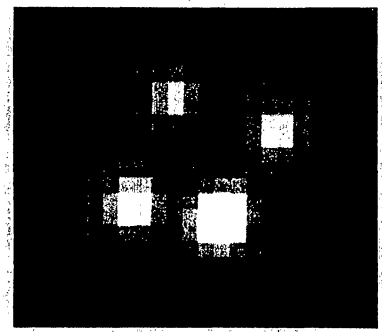
Figure 1: Accepted and proposed cases of multiply imaged quasars and radio sources.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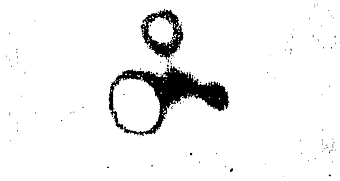
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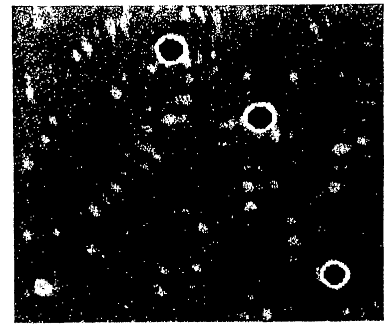
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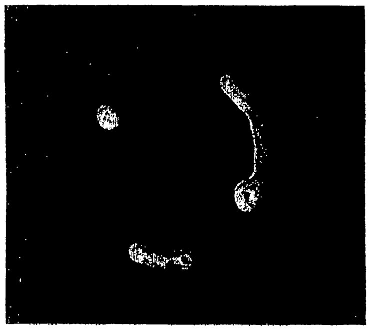
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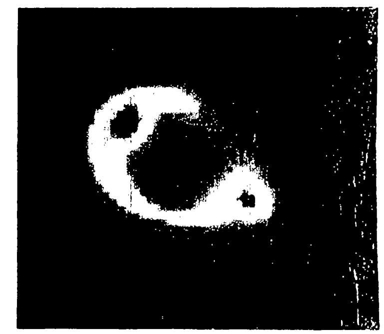
Fig.	Source name	Image(s)	Waveband/Telescope	Courtesy of
l	H 1413+117	A-D	Optical R / NTT	Liège Group
m	MG 0414+0534	A-D + Lens	Optical R / CFH + NTT	Dr. C. Vanderriest
n	B 1422+231	A-D	Radio (5 GHz) / MERLIN	Dr. A. Patnaik
o	B 1938+666	A-D + mini-arc	Radio (5 GHz) / MERLIN	Dr. A. Patnaik
p	MG 0751+2716	A-D + mini-arc	Radio (5 GHz) / MERLIN	Dr. J. Lehár
q	MG 1131+0456	A-B + Ring	Radio (8.4 GHz) / VLA	NRAO
r	MG 1654+1346	Ring	Radio (5 GHz) / VLA	NRAO
s	PKS 1830-211	A-B + Ring	Radio (5 GHz) / MERLIN	Dr. A. Patnaik
t	MG 1549+3047	Ring	Radio (8.4 GHz) / VLA	Dr. J. Lehár
u	B 0218+357	A-B + Ring	Radio (5 GHz) / MERLIN	Dr. A. Patnaik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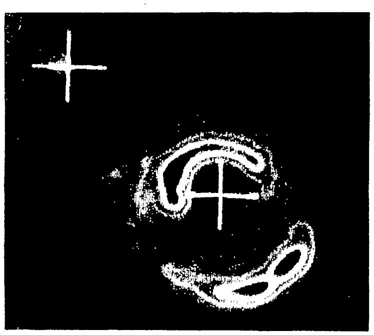
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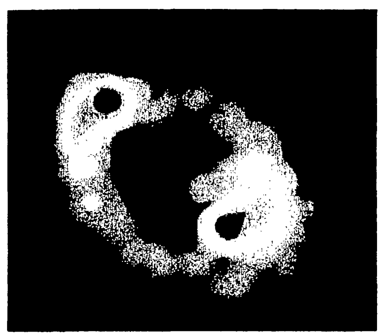
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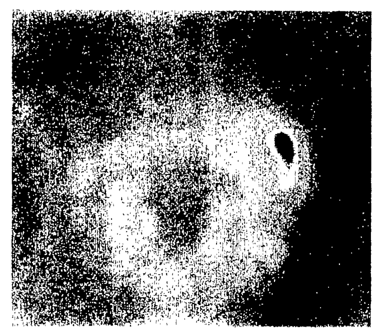
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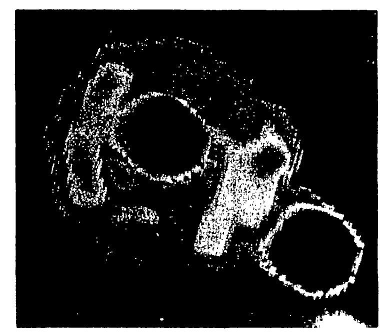
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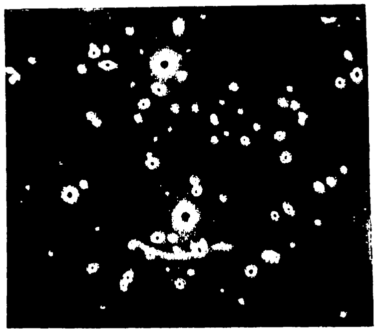
Figure 2: Accepted cases of multiply imaged quasars, radio sources, mini arcs and rings.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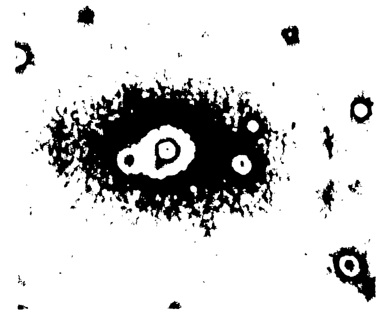
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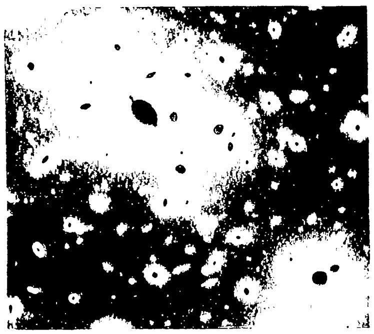
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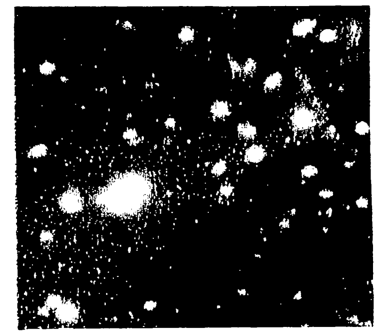
Fig.	Cluster lens + luminous arc(s)	Waveband/Telescope	Courtesy of
a	Abell 370	Optical I / CFH	Toulouse Group
b	Cl 2244-02	Composite optical B, V, R / CFH	Dr. F. Hammer
c	Abell 963	Composite optical B, R / Hawaii 2.2m	Dr. R. Lavery
d	Cl 0024+17	Optical B / CFH	Toulouse Group
e	Abell 2218	Optical r / Calar Alto 3.5m	Toulouse Group
f	Abell 2390	Optical I / CFH	Toulouse Group
g	Abell 2163	Optical B / CFH	Toulouse Group
h	Cl 2137-23	Optical B / CFH	Toulouse Group
i	Cl 0302+17	Composite optical B, R, I / CFH	Toulouse Group
j	MS 0440+0204	Composite optical B, V, R, I / CFH	Dr. F. Hammer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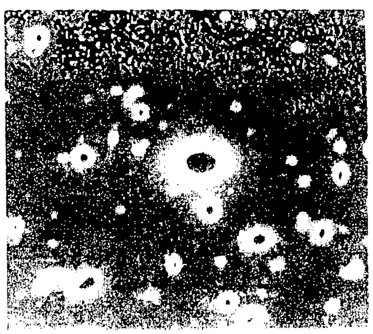
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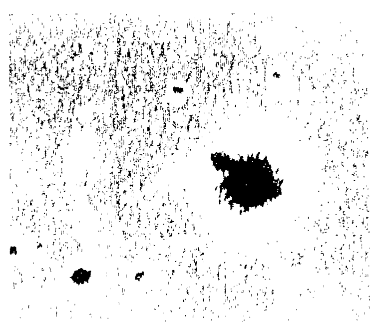
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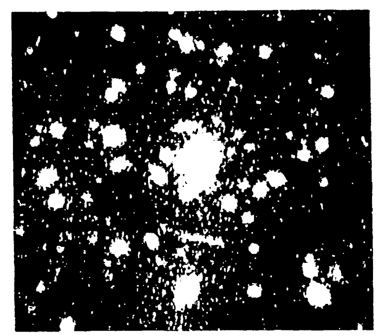
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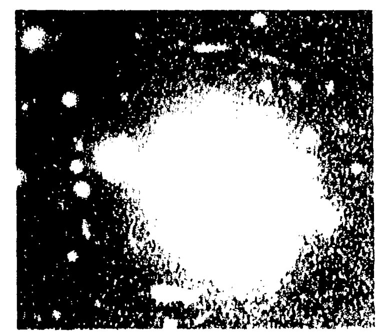
j

Figure 3: Accepted cases of giant luminous arcs and arclets.