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403. Wilson, T. L. 1972, *Astron. and Ap.*, **19**, 354.
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419. Zuckerman, B., *et al.* 1971, *Ap. J.*, **163**, L41.
420. Zuckerman, B., *et al.* 1970, *Ap. J.*, **160**, 485.
421. Zuckerman, B., *et al.* 1972, *Ap. J.*, **173**, L125.
422. Zuckerman, B., *et al.* 1971, *Ap. J.*, **169**, L105.
423. Zuckerman, B. and Palmer, P. 1970, *Astron. and Ap.*, **4**, 244.
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D. EXTRAGALACTIC RADIO ASTRONOMY 1969–1972

H. van der Laan and G. K. Miley

Radio astronomy shows increasing astrophysical diversity and the extragalactic branch ranges from spiral structure through relativistic astrophysics of nuclei of galaxies and quasars to observational cosmology. A bibliographic listing of about 700 papers under almost forty headings and subheadings has been prepared which systematically covers the subjects within our terms of reference. We list all relevant articles published in the journals listed in Section B(i), covering the period from July 1969 to November 1972. Comprehensive accounts of the subject may be found in the

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1971 proceedings of the Vatican Semaine d'Etude and the Uppsala IAU Symposium No. 44. These are listed under 'Reviews' and the individual articles have not been included separately in any other category. Each publication is designated by a minimal, abbreviated reference.

Some features of the work covered in this report are the rapid growth of data for radio sources and the promising development of radio investigations of optically selected objects. Many surveys have added to the primary reservoir of catalogued sources which merit further study. These surveys now span a large frequency range and the intercomparisons have clarified the spectral relations of source counts and the frequency dependence of the radio luminosity function. Very deep surveys now in progress will hopefully enable selection effects to be distinguished from cosmologically relevant features.

Improved positional accuracy, provided especially by phase stable interferometry, has led to a large harvest of optical identifications and subsequent spectroscopic and photometric work reported in other commissions.

The last three years have seen the increasing use of the Earth rotation synthesis technique to derive high resolution brightness maps of extragalactic sources. The detailed brightness distributions of many sources was explained with some success by invoking ram pressure confinement by an extragalactic medium. Circular polarization was detected in several sources and a few one and two dimensional linear polarization maps were obtained. It is hoped that the wealth of high resolution polarization data which will shortly become available will help to restrict the range of magnetohydrodynamic confinement models. Also, since both angular size and linear polarization have been shown to be well correlated with redshift, a study of the polarization distributions of high redshift objects may well impose useful constraints on possible cosmological models.

The use of very long baseline interferometers has become more widespread and one of the most interesting 'VLBI' results has been the observation of apparent expansion in a number of compact radio sources. For some quasars these data might imply highly relativistic expansion ('superlight velocities') if the quasar redshifts are cosmological in origin. Although their interpretation is still uncertain, it appears probable that the expansions are not real but, merely an effect produced by intensity variations between spatially separated regions within the sources.

Increasingly radio telescopes are turned, not to sources first listed in radio catalogues, but to nearby classical stellar systems and moderately distant optically conspicuous galaxies. In the period reported here a promising start was made with high resolution studies of neutral hydrogen distribution and kinematics in nearby galaxies. Combined with interferometric continuum studies these investigations have begun a new phase of spiral galaxy research. The advent of high resolution aperture synthesis telescopes and advances in electronic sensitivity will no doubt lead to many complementary and joint programmes of astronomers working in different spectral domains. For the investigation of radio galaxies and quasars this has been an impressively fruitful cooperation. It is to be expected that such combined efforts for nearer objects, much more amenable to detailed exploration, will soon result in exciting progress.

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(iii) Interferometric: Baselines > 3 km
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V. *Polarization Measurements*

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VIII. *Miscellaneous Observations*

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XX. *Review Papers etc.*

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(ii) Reviews

B. *Abbreviations*

(i)

AA Astronomy and Astrophysics
AASup Astronomy and Astrophysics Supplements
AdvAA Advances in Astronomy and Astrophysics
AJ Astronomical Journal
AJP Australian Journal of Physics
AJPSup Australian Journal of Physics Astrophysical Supplements
AnRev Annual Reviews of Astronomy and Astrophysics
Aph Astrophysica
ApSpSc Astrophysics and Space Science
ApJ Astrophysical Journal

ApJSup	Astrophysical Journal Supplements
ApL	Astrophysical Letters
ComA	Comments on Astrophysics and Space Sciences
MN	Monthly Notices of the Royal Astronomical Society
MRAS	Memoirs of the Royal Astronomical Society
Nat	Nature
NatPS	Nature Physical Sciences
Obs	Observatory
PASA	Proceedings of the Astronomical Society of Australia
PASJ	Publications of the Astronomical Society of Japan
PASP	Publications of the Astronomical Society of the Pacific
PRL	Physical Review Letters (not comprehensively searched)
QJ	Quarterly Journal of the Royal Astronomical Society
Sc	Science
SovAJ	Soviet Astronomical Journal

(ii) *Column headings*

frq, freqs	frequency or frequency range of observations in gigahertz
flx min	minimum flux density in survey/in units of 10^{-26} W Hz^{-1} m^{-2}
N	No. of sources dealt with in article

(iii) *Number of sources dealt with in article; N*

a	$N > 100$
b	$100 \geqslant N > 10$
c	$N < 10$
v	The subscript v denotes that variability is specifically studied

(iv) *Notes and comment*

decl	declination
e.a.	*et al.*
gal	galaxies
ident	identification
ired	infra-red
NRAO	National Radio Astronomy Observatory, Green Bank
opt	optical
qso	quasi-stellar objects
r.a.	right ascension
rgal	radio galaxy
RRE	Royal Radar Establishment, Malvern
spec	spectrum
s. state	steady state
Stephan Qu.	Stephan's Quintet
VLBI	very long baseline interferometry
Wbk	Westerbork

I. SURVEYS

frq	flx min	N	
.18	2.5	a	Caswell, Crowther 69*MN* **145**, 181
.41	.01	a	Pooley 69*MN* **144**, 101
.41	.07	a	Windram, Kenderdine 69*MN* **146**, 265
.41	.2	a	Davies 70*PASA* **1**, 340
.41	.2	a	Colla e.a. 70*AASup* **1**, 281
.41	.02	a	Willson 70*MN* **151**, 1
.41	.6	a	Willson 72*MN* **156**, 7
.41	.2	a	Colla e.a. 72*AASup* **7**, 1
.61	.8	a	Wendker e.a. 70*AJ* **75**, 148
.61	.8	a	Dickel e.a. 71*AJ* **76**, 294
1.4	.2	a	Ehman e.a. 70*AJ* **75**, 351
1.4	.2	a	Brundage e.a. 71*AJ* **76**, 777
1.4	.09	b	Maslowski 71*AA* **14**, 215
1.4	.09	b	Maslowski 72*AA* **16**, 197
1.4	.2	a	Willson 72*MN* **156**, 7
2.7	.1	a	Wall e.a. 71*AJPSup* **19**
2.7	.3	a	Shimmins 71*AJPSup* **21**
5.0	.07	a	Davis 71*AJ* **76**, 980
5.0	.09	a	Pauliny-Toth e.a. 72*AJ* **77**, 265

II. FLUX DENSITY MEASUREMENTS

(i) *Optically selected sources: Detections and Measurements*

Object	Freqs	*N*	
Gal	.41	b	Longair e.a. 70*ApL***7**, 23
Gal	.41	a	Cameron 71*MN***152**, 403
Gal	1.4	b	van der Kruit 71*AA***15**, 110
Gal	2.6	a	Rogstad, Ekers *ApJ***157**, 481
Gal	2.7	b	Kazés e.a. 70*ApL***6**, 193
Gal	2.7, 15	a	Heeschen 70*AJ***75**, 523
Gal	5.0	a	Whiteoak 70*ApL***5**, 29
Gal	8.5	c	Kuril'chik e.a. 70*SovAJ* **13**, 881
Maffei1	1.4		Oort 71*Nat***230**, 103
Maffei2	.18, 1.4		Caswell 71*Nat***231**, 35
Maffei2	3.2, 11		Bell e.a. 70*ApJ***161**, L13
Maffei2	3.2, 11		Bell, Seaquist 72*ApJ***173**, 257
Maffei2	.61, 2.7		Webber, Willis 71*Nat***231**, 36.
NGC604	1.4		Wright 71 *ApL***7**, 209
NGC5128	2.7, 8.1		Wade e.a. 71*ApJ***170**, L11
QSO	.32	b	Lang, Terzian 69*ApJ***158**, L11 Grueff 70*ApJ***160**, L41
QSO	2.7, 8.1	b	Wardle, Miley 71*ApJ***164** L119
QSO	31, 86	b	Conklin 70*Nat***227**, 1119

(ii) *Other flux density measurements*

Freqs	*N*	
.01	c_v	Bridle, Caswell 70*Nat* **225**, 356
.02	$3C84_v$	Roger 69*ApL***4**, 139
.04, 5	a(3C)	Kellermann e.a. 69*ApJ* **157**, 1
.32, .61	b	Jauncey e.a. 70*ApJ* **162**, L31
.01, .03	b	Braude e.a. 70*ApL***5**, 129
.41, 1.4	b	Hunstead, Jauncey 70*MN***149**, 91
.41, 5.0	$P1514\text{-}24_v$	Hunstead 71*Nat***233**, 401
.41	b	Jauncey 72*AJ***77**, 345
.41	a(4C)	Fanti e.a. 69*AA***2**, 477
.61, 13.5	b	Wills e.a. 71*ApJ***169**, L87
.41	a(4C)	Munro 71*AJP***24**, 263
.41	a(4C)	Munro 72*AJPSup***22**
.43	a	Backer e.a. 70*AJ***75**, 529
.61, 11	b(Ohio)	Kraus, Andrew 70*ApJ***159**, L41
.61, 11	b(Ohio)	Kraus, Andrew 70*ApJ***159**, L45
0.61, 85	c	Andrew e.a. 71*PASP***83**, 87
.75	b	Rzhiga, Frunova 69*SovAJ***13**, 28
.75, 11	c_v	Ross 70*Nat***226**, 431
1.4	a	Fomalont, Moffet 71*AJ***76**, 5
1.4	b(5C1)	Maslowski 71*AA***14**, 215
1.4	b(5C1/2)	Maslowski 72*AA***16**, 197
1.4	b(5C3)	van der Kruit, Katgert 72*ApL***11**, 181
1.4	a	Bridle e.a. 72*AJ***77**, 405
1.4	$BLLac_v$	Gower 69*Nat***224**, 569
2.3	c_v(VLBI)	Gubbay e.a. 69*Nat***224**, 1094
2.3	C_v(BLLac-type)	Nicolson 71*NatPS***233**, 155
2.3	P2204-24	Tritton, Nicolson 72*ApL***11**, 187
2.7	a(4C)	Wall 71*AJPSup***20**
2.7	b	Ames 70*AJ***75**, 71
2.7, 5.0	a	Witzel e.a. 71*AA***11**, 171
2.7	b_v	Witzel, Veron 71*ApL***7**, 225
2.7	b_v	Wills 71*ApJ***169**, 221
2.7	b_v	Grahl, Grewing 69*ApL***4**, 107
2.7	b	Browne, McEwan 72*NatPS***239**, 101
2.7, 5.0	c	Fanaroff, Blake 72*MN***157**, 41
2.7	c(Ohio)	Kraus, Andrew 71*AJ***76**, 103
2.7, 5	a(weak)	Pauliny-Toth, Kellermann 72*AJ***77**, 560
3.2, 11	c_v	MacDonell, Bridle 71*NatPS***234**, 88
3.2, 11	c_v(BLLac-type)	MacDonell, Bridle 70*Nat***227**, 582
4.5	c_v	Lipovka 69*SovAJ***13**, 21
5.0	a	Shimmins e.a. 69*AJPSup***8**
5.0	a	Shimmins, Bolton *AJPSup***23**

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Freqs	N		Freqs	N	
5.0	a(B2)	Grueff 71*AJ*76, 530	9.6	a	Berge, Seielstad 69*ApJ*157, 35
5.0	OQ208	Ryle, Pooley 69*ApL*4, 137	11	a	Doherty e.a. 69*AJ*74, 827
6.6,11	a	Bell e.a. 71*AJ*76, 524	11	b_v	Harvey e.a. 72*ApL*11, 147
6.6,11	$BLLac_v$	Andrew e.a. 69*Nat*223, 598	18,31	c_v	Hobbs, Waak 70*ApJ*161, 793
6.6,11	$OJ287_v$	Andrew e.a. 71*ApL*9, 151	19	c_v	McCullough, Waak 69*ApJ*158, 849
6.6,11	c_v	Locke e.a. 69*ApJ*157, L81	31,85	b	Kellermann, Pauliny-Toth 71*ApL*8, 153
7.8	$3C120_v$	Dent 72*ApJ*175, L55	36,130	$3C273_v$	Efanov e.a. 71*SovAJ*15, 338
8.0	b_v	Brandie 72*AJ*77, 197	69	b	Hobbs e.a. 69*AJ*74, 824
8.0	b(rgal)	Stull 71*AJ*76, 1	85	$OJ287_v$	Kinman, Conklin 71*ApL*9, 147
8.0	b(rgal)	Stull 71*AJ*76, 970	90	b_v	Fogarty e.a. 71*AJ*76, 537
8.0	b_v	Stull 72*AJ*77, 13			
8.0	c_v	Brandie, Stull 71*NatPS*231, 149			
8.0	$PO048\text{-}09_v$	Stull (70*Nat*225, 832)			
8.0,11	$BLLac_v$	Macleod e.a. 71*ApL*9, 19			

(iii) *Flux density scales and absolute measurements*

Dmitienko e.a. 71*SovAJ*15, 340
Scott, Shakeshaft 71*MN*154, 19P
Baars, Hartsuijker 72*AA*17, 172
Conway, Munro 72*MN*159, 21P
Medd 72*ApJ*171, 41
Wrixon e.a. 72*ApJ*174, 399

III. POSITION MEASUREMENTS

(i) *Better than* ~1″

N	Note		N	Note	
b	VLBI	Cohen, Shaffer 71*AJ*76, 91	b	Occultation	Swarup e.a. 71*ApL*9, 53
b	VLBI	Cohen 72*ApL*12, 81	APLib	Occultation	Kapahi 71*NatPS*234, 49
b	NRAO	Wade 70*ApJ*162, 381	3C273B	Occultation	Hazard e.a. 71*NatPS*233, 89
b	NRAO	Wade, Miley 71*AJ*76, 101	3C279	Relativity	Seielstad e.a. 70*PRL*24, 1373
a	RRE	Adgie e.a. 72*MN*159, 233	3C279	Relativity	Muhleman e.a. 70*PRL*24, 1377
b	Cambridge	Smith 71*NatPS*232, 150	3C279	Relativity	Sramek 71*ApJ*167, L55
c	Occultation	Gulkis e.a. 69*ApJ*157, 1047	3C279	Relativity	Hill 71*MN*153, 78

(ii) *Better than* ~ 5″

N	Note		N	Note	
b	Cambridge	Elsmore, Mackay 69*MN*146, 361	b	Wbk/M31	van der Kruit, Katgert 72*ApL*11, 181
a	Cal Tech	Fomalont, Moffet 71*AJ*76, 5	a	Decl	Moseley e.a. 70*AJ*75, 1015
b	Gal	van der Kruit 71*AA*15, 110	b	NRAO/gal	Heeschen 70*AJ*75, 523

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N	Note		N	Note	
a	Molonglo	Hoskins, Murdoch 70*AJPSup* **15**	a	R.A.	Clarke e.a. 69*AJPSup* **10**
a		Bridle e.a. 72*AJ* **77**, 405	b	QSO	Browne, McEwan 72*NatPS* **239**, 101
a	Molonglo	Hoskins, Murdoch 70*AJPSup* **15**	OQ208		Ryle, Pooley 69*ApL* **4**, 137
b	Molonglo	Hunstead e.a. 70*MN* **149**, 91	P1514-24		Hunstead 71*Nat* **233**, 401
a	Molonglo	Munro 71*AJP* **24**, 263			
a	Molonglo	Hunstead 72*MN* **157**, 367			

(iii) *Less accurate*

N		N	
a	Hazard e.a. 69*AJ* **74**, 833	a	Bolton e.a. 71*AJP* **24**, 889
a	Wills e.a. 69*AJP* **22**, 775	a	Wall e.a. 71*AJPSup* **19**
a	Backer e.a. 70*AJ* **75**, 529	a	Wall 71*AJPSup* **20**
b	Whiteoak 70*ApL* **5**, 29	b	Wills e.a. 71*ApJ* **169**, L87
b	Kazés e.a. 70*ApL* **6**, 193	b	Jauncey, Hunstead 72*AJ* **77**, 345
a	Witzel e.a. 71*AA* **11**, 171	a	Munro 72*AJPSup* **22**
a	Davis 71*AJ* **76**, 980		

(iv) *Position comparisons*

Note		Note	
Opt/radio	Shakeshaft 69*Obs* **89**, 209	Opt/NRAO/RRE	Argue, Kenworthy 70*Nat* **228**, 1076
NRAO/RRE	Wade e.a. 70*Nat* **228**, 146	178/408MHz	Munro, Hoskins 70*PASA* **1**, 341
Opt/NRAO	Sandage e.a. 70*ApJ* **162**, 399		

IV. BRIGHTNESS DISTRIBUTION MEASUREMENTS

(i) *Pencil beam*

c	Schilizzi 70*PASA* **1**, 337	M33	Terzian, Pankonin 72*ApJ* **174**, 293
b	Kazés e.a. 70*ApL* **6**, 193	M82	Feix 72*AA* **18**, 481
b gal	Cameron 71*MN* **152**, 439	Maffei 2	Bottinelli e.a. 71*AA* **12**, 264
a	Hunstead 72*MN* **157**, 367	Maffei 2	Bottinelli e.a. 71*AA* **13**, 497
Centaurus A	Lockhart, Sheridan 70*PASA* **1**, 344	Maffei 2	Webber, Willis 71*Nat* **231**, 36

(ii) *Interferometric: Baselines < 3 km*

N	Note		N	Note	
c		Hogg e.a. 69*AJ* **74**, 1206	b	Gal	Slee 72*ApL* **12**, 75
a		Ekers 69*AJPSup* **6**	b	E/SO gal	Heeschen 70*AJ* **75**, 523
a	5C3, M31	Pooley 69*MN* **144**, 101	b	QSO	Macdonald, Miley 71*ApJ* **164**, 237
b	3C	Mackay 69*MN* **145**, 31	c	M31	van der Kruit 72*ApL* **11**, 173
a		Windram, Kenderdine 69*MN* **146**, 265	M51, NGC5195		Mathewson e.a. 72*AA* **17**, 468
c	3C	Mitton 70*MN* **149**, 101	M51		Spencer, Burke 72*ApJ* **176**, L101
a	5C4 Coma	Willson 70*MN* **151**, 1	M82		Kronberg e.a. 72*ApJ* **173**, L47
c	3C	Mitton 70*ApL* **6**, 161	Maffei 2		Allen, Raimond 72*AA* **19**, 317
b		Fomalont 71*AJ* **76**, 513	NGC4631		Pooley 69*MN* **144**, 143
a		Bridle e.a. 72*AJ* **77**, 405	Stephan's Quintet		Allen, Hartsuijker 72*Nat* **239**, 324
b	3C	Branson e.a. 72*MN* **156**, 377			
c	Flat spec.	Fanaroff, Blake 72*MN* **157**, 41			
c	Clusters	Miley e.a. 72*Nat* **237**, 269			
b	Gal	Lequeux 71*AA* **15**, 30			

N	*Note*	
Virgo A		Graham 70*MN***149**, 319
Virgo A		Graham 71*Nat***231**, 253
3C9		Clark, Miley 69*ApL***4**, 183
3C33		Mitton 70*ApL***5**, 207

N	*Note*	
3C33		Mitton 70*ApL***5**, 287
3C272.1		Riley 72*MN***157**, 349
3C390.3		Harris 72*MN***158**, 1
3C459		Wardle 71*ApL***8**, 53
IIZw40		Jaffe 72*AA***20**, 461

(iii) *Interferometric: Baselines > 3 km*

N	
b	Donaldson e.a. 69*MN***146**, 213
b	Donaldson e.a. 71*MN***152**, 145
b	Broten e.a. 69*MN***146**, 313
c_v	Gubbey e.a. *Nat***224**, 1094
b	Jauncey e.a. 70*ApJ***160**, 337
c	Broderick e.a. 71*SovAJ***14**, 627
b	Kellermann e.a. 70*ApJ***161**, 803
b	Broderick e.a. 72*ApJ***172**, 299
b	Kellermann e.a. 71*ApJ***169**, 1
b_v	Knight e.a. 71*Sc***171**, 52
b_v	Whitney e.a. 71*Sc***172**, 225

N	
b	Cohen e.a. 71*ApJ***170**, 207
c_v	Legg e.a. 72*NatPS***235**, 147
Cygnus A	Mitton, Ryle 69*MN***146**, 221
Cygnus A	Miley, Wade 71*ApL***8**, 11
M82	Wilkinson 71*MN***154**, 1P
OP1934-63	Gubbay e.a. 71*AJ***76**, 965
Virgo A	Cohen e.a. 69*ApJ***158**, L83
Virgo A	Miley e.a. 70*ApJ***159**, L19/141
Virgo A	Wilkinson, Peckham 72*MN***156**, 7P
3C120	Shaffer e.a. 72*ApJ***173**, L147
3C147	Donaldson, Smith 71*MN***151**, 253

(iv) *Occultation*

c	Gulkis e.a. 69*ApJ***157**, 1047
c	Lang e.a. 70*ApJ***160**, 17
c	Hazard, Sutton 71*AJ***76**, 609
c	Hazard 72*ApL***11**, 139
b	Swarup e.a. 71*ApL***9**, 53
b	Lyne 72*MN***158**, 431
b	Clarke 72*AJP***25**, 215

(v) *Scintillation*

a	Bell-Burnell 72*AA***16**, 379
APLib	Kapahi e.a. 71*NatPS***234**, 49
APLib	Anathakrishnan e.a. 72*NatPS***235**, 167
3C48	Paniyan 69*Aph***5**, 291
3C273	Bell, Hewish 69*ApL***4**, 211
3C273	Antonova e.a. 69*Aph***5**, 283
3C273	Paniyan 70*Aph***6**, 165

V. POLARIZATION MEASUREMENTS

(i) *Integrated linear polarization*

Freqs	*N*	
.41, .61	a	Conway e.a. 72*MN***157**, 443
.61	a	Kronberg, Conway 70*MN***147**, 149
4.2	b_v	Tabara e.a. 72*PASJ***24**, 301
5.0	a	Gardner e.a. 69*AJP***22**, 821
6.6, 11	BLLac$_v$	Macleod e.a. 71*ApL***9**, 19
8.0	c_v	Aller 70*ApJ***161**, 1

Freqs	*N*	
8.0	3C279$_v$	Aller, Olsen 71*AJ***76**, 761
8.0	BLLac$_v$	Olsen 69*Nat***224**, 1008
9.6	b	Berge, Seielstad 69*ApJ***157**, 35
19	c	McCullough, Waak 69*ApJ***158**, 849
31	c	Hobbs, Waak 72*AJ***77**, 342
31	c	Wardle 71*ApL***8**, 183

(ii) *Linear polarization distribution*

c	Baldwin e.a. 70*MN***150**, 253
c	Seielstad, Weiler 71*AJ***76**, 211
b	Davies, Gardner 70*AJP***23**, 59
c	Gardner, Whiteoak 71*AJp***24**, 899
c	Wardle 71*ApL***8**, 183
c	Kronberg 72*ApJ***176**, 47
M51	Mathewson e.a. 72*AA***17**, 468
Cygnus A	Mitton 71*MN***153**, 133
3C20	Fomalont 70*ApJ***160**, L73
3C2721.1	Riley 72*MN***157**, 349
3C273	Conway, Stannard 72*NatPS***239**, 22
3C390.3	Harris 72*MN***158**, 1
3C459	Wardle 71*ApL***8**, 53

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(iii) *Circular polarization*

Seielstad 69*AA***2**, 372
Seaquist 70*ApL***5**, 111
Gilbert, Conway 70*Nat***227**, 585
Seaquist 71*NatPS***231**, 93
Conway e.a. 71*MN***152**, 1P
Biraud 72*AA***19**, 310
Roberts e.a. 72*NatPS***236**, 3

VI. NEUTRAL HYDROGEN OBSERVATIONS

(i) *Emission: Pencil beam*

Comment	
36 Gal	Bottinelli 71*AA***10**, 437
Early type gal	Bottinelli e.a. 70*AA***6**, 453
Sb/Sc gal	McCutcheon, Davies 70*MN***150**, 337
Scd gal	Rogstad, Shostak 72*ApJ***176**, 315
Small gal	Gouguenheim 69*AA***3**, 281
Small gal	Chamaraux e.a. 70*AA***8**, 424
Seyfert gal	Allen e.a. 71*AA***10**, 198
E gal	Gallagher 72*AJ***77**, 568
Opt/21 cm	Heidmann e.a. 71*MRAS***75**, 85
Opt/21 cm	Heidmann e.a. 71*MRAS***75**, 105
Opt/21 cm	Heidmann e.a. 71*MRAS***76**, 121
Opt/21 cm	Ford e.a. 71*AJ***76**, 22
Centaurus A	Whiteoak, Gardner 71*ApL***8**, 57
Centaurus A	Roberts 70*ApJ***161**, L9
IC310	Bottinelli e.a. 72*AA***18**, 121
M31	Davies, Gottesmann 70*MN***149**, 237
M31	Gottesmann, Davies 70*MN***149**, 263
M31	Whitehurst, Roberts 72*ApJ***175**, 347
M33	de Jager, Davies 71*MN***153**, 9
M33	Gordon 71*ApJ***169**, 235
M31/33	Gottesmann, de Jager 70*MRAS***74**, 67
M31/33	Gottesmann 70*MRAS***74**, 73
M31/33	de Jager 70*MRAS***74**, 123
M31/33	Gordon 69*ApL***4**, 47
M51	Roberts, Warren 70*AA***6**, 165
M82	Guelin, Weliachew 70*AA***9**, 155
M82	Weliachew 71*PASP***83**, 609
M101	Rogstad, Shostak 71*AA***13**, 99
M101	Rogstad, Shostak 71*AA***13**, 108
Maffei 2	Bottinelli e.a. 71*AA***12**, 264
Maffei 2	Bottinelli e.a. 71*AA***13**, 497
NGC45	Lewis 72*AJP***25**, 315
NGC253	Huchtmeijer 72*AA***17**, 207
NGC2403	Burns, Roberts 71*ApJ***166**, 265
NGC3109	Sizikoo 71*SovAJ***14**, 931
NGC4631/4656	Weliachew 69*AA***3**, 402
NGC5253	Bottinelli e.a. 72*AA***17**, 445
NGC5457	Guelin, Weliachew 70*AA***7**, 141
NGC5457	Guelin, Weliachew 70*AA***9**, 477
Stephan Qu.	Allen 70*AA***7**, 330
Virgo A	Allen 69*AA***3**, 316
IIZw40	Gottesmann, Weliachew 72*ApL***12**, 63

(ii) *Emission: interferometric*

Comment	
Techniques	Baldwin e.a. 71*MN***154**, 445
Techniques	Wright 71*ApJ***166**, 455
Sb/Sc gal	McCutcheon, Davies 70*MN***150**. 337
NGC604	Wright 71*ApL***7**, 209
M33	Wright e.a. 72*MN***155**, 337
Maffei 2	Love 72*NatPS***235**, 53

(iii) *Redshifted absorption*

Allen 69*AA***3**, 382
Bahcall, Ekers 69*ApJ***157**, 1055
Shuter, Gower 69*Nat***223**, 1046
Heiles, Miley 70*ApJ***160**, L83
Dent 71*ApJ***165**, 451
Seielstad e.a. 71*ApJ***170**, 219

VII. MICROWAVE BACKGROUND MEASUREMENTS

Penzias e.a. 69*ApJ***157**, 49
Alexander e.a. 69*ApJ***157**, L163
Clark e.a. 70*Nat***228**,847
Pipher e.a. 71*Nat***231**, 375
Henry 71*Nat***231**, 516
Boughn e.a. 71*ApJ***165**, 439
Mather e.a. 71*ApJ***170**, L59
Thaddeus 72*AnRev***10**, 305

VIII. MISCELLANEOUS OBSERVATIONS

OH in NGC253/M82	Weliachew 71*ApJ***167**, L47
H_2O	Dickinson, Chaisson 71*ApJ***169**, 207
Source grouping	Arp 72*ApJ***174**, L111
X-ray ident.	Costain e.a. 72*ApJ***175**, L15

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IX. OPTICAL IDENTIFICATIONS

N	
a	Wills, Bolton 69*AJP***22**, 775
a	Staff CSIRO 69*AJPSup***7**
c	Ryle, Pooley 69*ApL***4**, 137
a	Pooley 69 *MN***144**, 101
b	Mackay 69*MN***145**, 31
a	Windram, Kenderdine 69*MN***146**, 265
b	Elsmore, Mackay 69*MN***146**, 361
a	Braccesi e.a. 70*AA***6**, 268
b	Bajaja 70*AJ***75**, 667
a	Olsen 70*AJ***75**, 764
a	Moseley e.a. 70*AJ***75**, 1015
b	Hazard e.a. 70*AJ***75**, 1039
b	Lü 70*AJ***75**, 1161
b	Ekers 70*AJP***23**, 217
a	Bolton, Wall 70*AJP***23**, 789
c	Grueff 70*ApJ***160**, L41
b	Börngen e.a. 70*ApJ***162**, 337
c	Kristian, Sandage 70*ApJ***162**, 391
c	Blake e.a. 70*ApL***6**, 167
b	Jauncey, Hazard 70*ApL***7**, 1
b	Hunstead, Jauncey 70*MN***149**, 91
a	Willson 70*MN***151**, 1
c	Lynds, Wills 70*Nat***226**, 532
c	van den Bergh 70*PASP***82**, 1374
c	Hunstead e.a. 71*AJP***24**, 601
b	Bolton e.a. 71*AJP***24**, 889
a	Wall 71*AJPSup***20**
a	Munro 71*AJP***24**, 263
b	Shimmins e.a. 71*ApL***8**, 139
b	Swarup e.a. 71*ApL***9**, 53
c	Lü 71*Nat***229**, 477
c	Whiteoak, Gardner 71*Nat***231**, 108
c	Browne 71 *Nat***231**, 515
c	Hunstead 71*Nat***233**, 401
b	Hunstead 71*MN***152**, 277
c	Hill, Longair 71*MN***154**, 125
b	Véron 71*AA***11**, 1
c	Wlerick e.a. 71*AA***11**, 142
b	Radivich, Kraus 71*AJ***76**, 683
c	Wardle, Miley 71*ApJ***164**, L119
b	Boeshaar, Kraus 71*ApJ***165**, 445
c	Bond 71*ApJ***167**, L79
c	Kunkel, Bradt 71*ApJ***170**, L7
c	Wade e.a. 71*ApJ***170**, L11
c	Burbidge e.a. 71*ApJ***170**, 233
b	Penston 71*ApJ***170**, 395
a	Grueff, Vigotti 72*AASup***6**, 1
c	Wlerick, Lelièvre 72*AA***16**, 53
a	Pauliny-Toth e.a. 72*AJ***77**,265
b	Barbieri e.a. 72*AJ***77**, 444
b	Gearhart e.a. 72*AJ***77**, 557
c	Arp e.a. 72*ApJ***171**, L41
b	Burbidge e.a. 72*ApJ* **172**, 37
b	Lynds e.a. 72*ApJ***172**, 531
c	Oemler jr. e.a. 72*ApJ***176**, L47
b	Peterson, Bolton 72*ApL***10**, 105
b	Warnes 72*ApL***11**, 83
c	Tritton, Nicholson 72*ApL*11, 187
c	Wills, Lynds 72 *ApL***11**,189
a	Willson 72*MN***156**,7
a	Hunstead 72*MN***157**, 367
c	Bridle, Feldman 72*NatPS***235**, 168
b	Browne, Ewan 72 *NatPS***239**, 101

X. INTERPRETATION OF SPECTRAL DATA

3C Compendium	Kellermann e.a. 69*ApJ***157**, 1
R. gal evolution	Van der Laan, Perola 69*AA***3**, 468
3C/multiple components	Van der Laan 69*AA***3**, 4.77
Flux vs. spectral index	Daghesmamonski 69*Aph***5**, 297
Negative curvature	Vaisberg 69*SovAJ***13**, 205
Multiple sources	Bridle 69*Nat***224**, 889
Normal gal	Pronik 70*SovA***13**, 747
S/SO gal	Heeschen 70*ApL***6**,46
QSO/flux density	Dagkesamanskii 70*Nat***226**, 432
Rel. Maxw. distributions	Hirth 70*ApL***7**, 153
Interaction with background	Rowan-Robinson 70*MN***150**, 389
Statistics vs. structure	Kuril'chik 71*ApL***7**, 229
3C	Kuril'chik 71*SovAJ***14**, 630
3C	Kuril'chik 17 *SovAJ***14**, 924
Non-linear spectra	Braude e.a. 71*ApSpSc***12**, 349
Opt. variability	Folsom e.a. 71*NatPS***230**, 199
Power vs. spectral index	Véron, Witzel 72*AA***18**, 82
Luminosity correlation	Macleod,Doherty 72*Nat***238**, 88
Luminosity relation	Bridle e.a. 72*ApL***11**, 27

XI. INTERPRETATION OF VARIABILITY DATA/COMPACT SOURCES

3C 273 Particle accel.	Simon 69*ApJ***158**, 865
M87	Burbidge 70*ApJ***159**, L105
Model	Cavaliere e.a. 70*ApJ***162**, L133
Radio outbursts	Takarada 70*PASJ***22**, 551

Models	Rees, Simon 70*Nat* **227**, 1303
Intergalactic scintillations	Yoshioka 70*PASJ* **22**, 423
Structure/compact sources	De Young 71*ApL* **9**, 43
Expanding source model	Kogure 71*PASJ* **23**, 449
Changing images	Cavaliere 71*Sc* **173**, 525
3C120/opt. variability	Usher 72*ApJ* **172**, L25
Model constraints	Jones, Kellogg 72*ApJ* **172**, 283
Multiple bursts locations	Dent 72*ApJ* **175**, L55
3C279	Dent 72*Sc* **175**, 1105
3C279 expansion	Gregory 72*Nat* **239**, 56

XII. INTERPRETATION OF STRUCTURE DATA

Gen. discussion	Fomalont 69*ApJ* **157**, 1027
3C/correlations	Longair, MacDonald 69*MN* **145**, 309
Min. observable diam.	Harris e.a. 70*AA* **8**, 98
3C33/Ram pressure	Mitton 70*ApL* **5**, 207/287
S/SO Gal	Heeschen 70*ApL* **6**, 49
Spiral gal	Lequeux 71*AA* **15**, 42
Double sources/ram pressure	Wardle 71*ApL* **8**, 221
Orientations/E gal	Mackay 71*MN* **151**, 421
Quasars	Miley 71*MN* **152**, 477
Radio tails/clusters	Hill, Longair 71*MN* **154**, 125
3C/source properties	Mackay 71*MN* **154**, 209
Spectra, optical	Kuril'chik 71*SovAJ* **14**, 924
Cygnus A/ram pressure	Mills 72*ApL* **10**, 109
Radio trails/clusters	Miley e.a. 72*Nat* **237**, 269
Double sorces/ram pressure	Kuril'chik 72*SovAJ* **15**, 542

XIII. INTERPRETATION OF POLARIZATION DATA

Quasars/spectral index	Gilbert e.a.69*Nat* **223**, 1252
8GHz	Aller 70*ApJ* **161**, 19
Expanding source model	Aller 70*Nat* **225**, 440
Vs. redshift	Conway, Gilbert 70*Nat* **226**, 332
Vs. redshift	Gardner, Whiteoak 70*Nat* **227**, 585
Magn. field scales	Perola 71*AA* **14**, 337
Linear vs. circular	Melrose 71*ApL* **8**, 227
Rotation measures	Reinhardt 72*AA* **19**, 104
Rotation measures	Mitton, Reinhardt 72*AA* **20**, 337
3C Compendium	Mitton 72*MN* **155**, 373
Faraday depolarization	Strom 72*NatPS* **239**, 19

XIV. REDSHIFT DEPENDENT PROPERTIES OF SOURCES

Ang. size/weak sources	Longair, Pooley 69*MN* **145**, 121
Ang. size/double sources	Legg 70*Nat* **226**, 65
Polarization	Conway, Gilbert 70*Nat* **226**, 332
Flux/radio galaxies	Hoyle, Burbidge 70*Nat* **227**, 359
Polarization	Gardner, Whiteoak 70*Nat* **227**, 585
Ang. size	Miley 71*MN* **152**, 477
Opt. vs. HI/anomalous redshifts	Lewis 71*NatPS* **230**, 13
Criticism of Lewis	Arp 71*NatPS* **231**, 103
Faraday rotation	Arp 71*Nat* **232**, 463
Depolarization	Kronberg e.a. 72*MN* **156**, 275

XV. MISCELLANEOUS CORRELATIONS

Source pairs	Hinder, Branson 69*Obs* **89**, 178
Small source/opt. peculiar gal. nuclei	Tifft 70*ApL* **7**, 7
Source randomness/ isotropy	Wills 71*NatPS* **234**, 168
Source grouping	Arp 72*ApJ* **174**, L111
Seyferts/radio vs. infrared	Rieke, Low 72*ApJ* **176**, L95
Source orientation/ grouping	Willson 72*MN* **155**, 275

XVI. INTERPRETATION OF MICROWAVE BACKGROUND DATA

Hazard, Salpeter 69*ApJ* **157**, L87
Dautcort 69*MN* **144**, 255
Longair, Sunyaev 69*Nat* **223**, 719
Sunyaev, Zeldovich 69*Nat* **223**, 721
Brecher, Blumenthal 70*ApL* **6**, 169
Sunyaev, Zeldovich 70*ComA* **2**, 66
Rowan-Robinson 70*MN* **150**, 389
Rasband 71*ApJ* **170**, 1
Caroff, Petrosian 71*Nat* **231**, 378
Fanaroff, Longair 72*MN* **159**, 119

XVII. THEORY OF RADIO SOURCES

(i) *Radiation Theory*

Collective Bremstrahlung	Papadopoulos, Lerche 69*ApJ* **158**, 981
Relativistic Streaming	Noerdlinger 69*ApL* **4**, 233
Synchotron Developments	Ginzburg, Syrovatskii 69*AnRev* **7**, 375
Limitations/small pitch angles	O'Dell, Sartori 70*ApJ* **161**, L63
Turbulent plasma	Colgate e.a. 70*ApJ* **162**, 649
Anisotropic emission	Kuril'chik 70*SovAJ* **14**, 21
Small pitch angles	Melrose 71*ApL* **8**, 35
Plasma approximations	Wild, Hill 71*AJP* **24**, 43
Circ. polarization	Pacholczyk, Swihart 71*MN* **153**, 3P
Compton/spectrum depression	Getmansev, Tokarev 72*ApL* **12**, 57
Circ. polarization	Rosenberg 72*AA* **19**, 66

(ii) *Effects of Compton Scattering*

Secondary electrons	Perola 69*AA* **3**, 481
Electron acceleration	Burke, Layzer 69*ApJ* **157**, 1169
Low freq. cut-off	O'Dell, Sartori 70*ApJ* **162**, L37
Low freq. spectrum	Sunyaev 70*ApL* **7**, 19
Radiative heating	Levitch, Sunyaev 70*ApL* **7**, 69
Compact sources	Walmsley 71*ApL* **8**, 27
Spectrum bending	Jaffe, Treves 71*ApL* **9**, 39
Low freq. spectrum	Sunyaev 71*SovAJ* **15**, 190
Compact sources	Olster, Alschuler 71*ApSpSc* **10**, 431
Superlight sources	Ginzburg 72*ComA* **4**, 41

(iii) *Source models*

QSO's/pulsars	Morrison 69*ApJ* **157**, L73
Rotating collapsed objects	Cavaliere e.a. 69*ApL* **4**, 103
Galactic nuclei-old quasars	Lynden-Bell 69*Nat* **223**, 690
Formation of jets	Bisnovatyi-Kogan e. a. 69*SovAJ* **13**, 369
Patching model	Melik-Alaverdion 70*Aph* **6**, 341
Electrodynamic model	Piddington 70*MN* **148**, 131
Pulsar in QSO's	Sturrock 71*ApJ* **170**, 85
Multiple explosions/heating	Christiansen 71*ApL* **7**, 233
Magn. field generation	Bisnovatyi-Kogan, Vainstein 71*ApL* **8**, 151
Synchro-compton	Rees 71*Nat* **229**, 312
Synchro-compton	Jennison 71*NatPS* **231**, 88
Outbursts	Shklovsky 71*SovAJ* **14**, 594
Synchro-compton	Blandford 72*AA* **20**, 135
Energy source/structure	Daltabuit, Cox 72*ApJ* **173**, L13
Gal. & QSO activity	Sturrock, Barnes 72*ApJ* **176**, 31
Nuclei ejection	Shklovsky 72*ApL* **10**, 5
Synchro-compton	Blandford, Rees 72*ApL* **10**, 77
Variability	Kuril'chik 72*ApL* **10**, 115
Superlight expansion	Richter 72*NatPS* **237**, 71

(iv) *Magnetohydrodynamics/Source Confinement*

Ram pressure model	Christiansen 69*MN* **145**, 327
Particle diffusion	De Young 70*AA* **9**, 125
Ram pressure model	Mills, Sturrock 70*ApL* **5**, 105
3C33	Mitton 70*ApL* **5**, 207/287
Hydromagnetic bubbles/double sources	Levy 71*ApJ* **164**, 23
Dynamics/extended sources	De Young 71*ApJ* **167**, 541
Ram pressure vs. observations	Wardle 71*ApL* **8**, 221
Cygnus A	Mills 72*ApL* **10**, 109
Ram pressure instabilities	Blake 72*MN* **156**, 67
Gas in clusters	Miley e.a. 72*Nat* **237**, 269

XVIII. SOURCE COUNTS AND RELATED TOPICS

(i) *Data*

Frq		
.41	4C Identifications	Munro 71*AJP* **24**, 617
1.4	Ohio	Harris, Kraus 70*Nat* **227**, 785
	Ohio flux error	Jauncey, Niell 71*NatPS* **229**, 223
	Ohio flux error	Harris, Kraus 71*NatPS* **230**, 140
	Ohio extension	Kraus 72*NatPS* **236**, 5
1.4	Spectral indices	Willson 72*MN* **155**, 385
1.4		Bridle e.a. 72*NatPS* **235**, 123
5.0		Kellermann e.a. 71*ApJ* **170**, L1
8.0	Flat spectra	Brandie 70*Nat* **225**, 352

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(ii) *Interpretation and luminosity functions*

Counts/review	Brecher e.a. 71*ComA***III**, 99
Counts/review	Longair, Rees 72*ComA***IV**, 79
Luminosity-volume test	Schmidt 70*ApJ***162**, 371
Luminosity-volume test	Longair, Scheuer 70*MN***151**, 45
Luminosity-volume test	Rees, Schmidt71*MN***154**, 1
Luminosity-volume test	Caswell, Weyman 72*MN***156**, 19P
Luminosity-volume test	Lynds, Petrosian 72*ApJ***175**, 591
Evolutionary effects/ qso's	Arakelian 69*Aph***5**, 461
Evolutionary effects/ qso's	Arakelian 69*Aph***5**, 603
Sources-background/ s.state	Hazard, Salpeter 69*ApJ***157**, L87
Source evolution/ background	Longair 70*MN***150**, 155
Sources/interaction with background	Rowan-Robinson 70*MN***150**, 389
Fitting count data	Crawford e.a. 70*ApJ***162**, 405
Luminosity function	Windram, Kenderdine 69*MN***146**, 265
Luminosity evolution/ qso's	Arakelian 70*Nat***225**, 358
Luminosity function/ qso's	Arakelian 70*Aph***6**, 531
Luminosity function/ rgal	Alaverdian 70*Aph***6**, 54
Evolution/large z	Doroshkevich, Longair 70*MN***147**, 139
Evolution function	Ringenberg, McVittie 70*MN***149**, 341
Counts/interpretation	Rowan-Robinson 70*MN***149**, 365
Quasar evolution	Cavalier e.a. 71*ApJ***170**, 223
Rgal evolution	Rowan-Robinson 71*Nat***229**, 388
Criticism of R. Robinson	Mackay 71*Nat***233**, 402
Criticism of Mackay	Rowan-Robinson 71*Nat***233**, 403
Luminosity vs. density evolution	Davidson 70*Nat***227**, 357
Luminosity vs. density evolution	Davidson e.a. 71*AJP***24**, 403
Secular evolution	Davidson 71*MN***154**, 339
Observational selection/ 3C qso's	Lynden-Bell 71*MN***155**, 95
Bright galaxies	Cameron 71*MN***152**, 429
Rgal luminosity function	Merkelijn 71*AA***15**, 11
QSO/opt and radio	Arakelian 71*Aph***7**, 457
QSO luminosity evolution	Golden 71*NatPS***234**, 103
Density/luminosity function	Edwards 71*NatPS***232**, 59
Reply to Edwards	Longair 71*NatPS***232**, 59
Rgal, QSO evolution	Bahcall 72*ApJ***172**, 265
QSO evolution	Schmidt 72*ApJ***176**, 273
Rgal evolution	Schmidt 72*ApJ***176**, 289
Source count interpret.	Schmidt 72*ApJ***176**, 303
Evolution/large sources	Fanaroff, Longair 72*MN***159**, 119

XIX. MISCELLANEOUS RADIO-COSMOLOGY

Antipodal images/ cosmology	Andretch, Dehnen 69*AA***3**, 252
Ghost images/ statistics	Petrosian, Ekers 69*NatPS***224**, 484
Metagalactic field/ Faraday rotation	Kawabàta e.a. 69*PRASJ***21**, 293
Intergal. magn. field	Brecher, Blumenthal 70*ApL***6**, 169
Faraday rotation/ cosmology	Burman 72*PASJ***24**, 291
Cluster magn. field	Perola, Reinhardt 72*AA***17**, 432
Grav. deflection/ relativity	Seielstad e.a. 70*PRL***24**, 1373
Grav. deflection/ relativity	Muhleman e.a. 70*PRL***24**, 1377
Grav. deflection/ relativity	Sramek 71*ApJ***167**, L55
Grav. deflection/ relativity	Hill 71*MN***153**, 78
Local/cosmological QSO's	Rowan-Robinson 72*Nat***236**, 112

XX. REVIEW PAPERS ETC.

(i) *Compendia of data*

Parkes catalogue	CSIRO staff 69*AJPSup***7**
3C spectra	Kellermann e.a. 69*ApJ***157**, 1
Sources/master list	Dixon 70*ApJSup***20**, 1
QSO's	De Veny e.a. 71*PASP***83**, 611
3C polarizations	Mitton, 72*MN***155**, 373

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(ii) *Reviews*

Nuclei of gal.	Semaine d'Etude 71, Vatican	Radio Astrophysics	Pacholczyk 70Freeman
Gal/QSO-*IAUSymp*. **44**	Evans 70Reidel	Compact Gal/QSO's	Zwicky 70*AdvAA*7, 228
Short μ wave obs.	Foster 69*QJ***10**, 206	Energy problems	Ryle 70*QJ***11**, 429
History/M33	Gordon 69*QJ***10**, 293	Unsolved problems	Bahcall 71*AJ***76**, 283
Synchotron developments	Ginzburg, Syrovatskii 69*AnRev***7**, 375	Cosmical constant	McCrea 71*QJ***12**, 140
QSO's	Schmidt 69*AnRev***7**, 527	Magn. fields	Cowling 71*QJ***12**, 348
High resolution observations	Cohen 69*AnRev***7**, 619	Magnetohydrodynamic stability	Tayler 71*QJ***12**, 352
QSO's	Burbidges 69*Nat***224**, 21	Source counts/ theories	Brecher e.a. 71*ComA***3**, 99
Infra-red/μ wave	Feldman e.a. 69*Nat***224**, 752	Nature of redshifts	Arp 71*Sci***174**, 1189
Gal nuclei	Burbidge 70*AnRev***8**, 369	Cosmic ray electrons	van de Hulst 72*QJ***13**, 10
		Source counts/ interpretation	Longair, Rees 72*ComA***4**, 79

RADIO ASTRONOMY INSTRUMENTS

R. Wielebinski

1. *Radio telescopes*

The last three years saw the completion of a number of large radio telescopes. New filled aperture telescopes and a number of array and synthesis array telescopes will be described. A very useful discussion of all aspects of radio telescopes can be found in a book by Christiansen and Högbom (**1**).

Filled apertures

A survey of filled aperture radio telescopes was made by Findlay (**2**). Of the fully steerable paraboloidal reflectors completed, the largest is the 100-m radio telescope (**3, 4**) of the Max-Planck-Institut für Radioastronomie. One of the features of the telescope is the use of 'homologous' design. The elastic structure supporting the paraboloidal surface deforms into a series of paraboloids as the telescope is tipped from zenith to the horizon. The changing focus position can easily be followed with small movements of the feed. The MPIfR 100-m telescope operates successfully at 2·8 cm wavelength indicating the usefulness of the design principle. A number of smaller reflectors usable down to mm-wavelengths have also been completed. Data on high resolution mm-reflector antennas has been summarized by Cogdell *et al.* (**5**). Details of the 22-m dish in Crimea capable of operation down to 1 mm wavelength can be found separately (**6**). Studies of larger mm-wave telescopes have also been completed in view of the rapid development of mm wavelength spectroscopy, and construction of such antennas can be expected in the future.

Array telescopes

Numerous unfilled aperture telescopes have come into operation during the last three years. The largest of these is the 5-km synthesis array at Cambridge (**7**) which will have a resolution of 2″ at 6-cm wavelength. The Westerbork synthesis array (**8**) is now fully operational at 6 cm, 21 cm and 49 cm. The Fleurs telescope, the first synthesis telescope in the southern sky was commissioned in 1972 (**9**). One of its features is the simultaneous correlation for all interferometer pairs allowing a synthesis to be complete after 12 hr of observing. Another synthesis instrument is Stanford's high resolution radio interferometer (**10**). One of the more novel instruments to become operational in this period is the Ooty array (**11**). This telescope uses the natural geographical position (latitude 11°) to give a telescope which requires to be steered only in one axis. Numerous lunar occultations have been observed.

The advent of space radio astronomy was announced in the last report. Improvements allow observations to be carried out in the frequency range from some 100 kHz to 10 MHz (**12**).

Numerous other instruments, smaller than those reported here have become operational in the past three years. They are too numerous to be included here.

2. *Antenna feeds*

The efficient use of any reflector radio telescope depends on the use of good feeds. This is particularly true for large paraboloidal or spherical reflectors. The field distributions in the focal region have been investigated (**13, 14**) and can readily be computed. Then a feed must be designed which on immersion in these fields matches the energy distribution without altering the amplitude and phase relations. One of the most successful methods is to use a hybrid mode feed (**15**). For deep paraboloidal dishes feeds based on a scalar horn design have been developed (**16**). Another approach has been the use of coaxial waveguides (**17**) with exact control of phase and amplitude. Efficiencies of 80% are being approached in practice depending on the complexity of the feed.

3. *Receivers*

There has been a steady development of receiver front-ends and an explosive development in the field of digital hardware.

Front-ends

There has been an extension in the frequency range, reduction in the receiver noise and increase in the bandwidth of parametric amplifiers. Uncooled parametric amplifiers have been made to operate at 46 GHz (**18**) using waveguide mounted varactor diodes. Cooled parametric amplifier performance has been steadily improved by the use of higher pump frequencies, better diodes and improvements in design of cooled circulators. Low-loss cooled circulators (**19**) are a critical component and can now be commercially produced by a number of manufacturers, resulting in low receiver noise temperatures. The MASER as a front-end receiver is being reinvestigated particularly for high frequencies. The maser has a somewhat lower nôise temperature but only a narrow bandwidth, but this is no disadvantage for most spectral line observations. For mm-wavelengths receivers from Bell Telephone Laboratories (**20**) and NRAO using specially developed Schottky-barrier diodes mounted in a waveguide appear to be the only practically successful devices. However, this field of receiver technology is in rapid development and hopefully, a significant breakthrough may be at hand.

Back-ends

In the last three years rapid development took place in the field of receiver systems, particularly in digital hardware. Each large observatory now has a large autocorrelation spectrograph. Descriptions can best be found in internal reports, and the NRAO Electronics Series can be particularly recommended for reference. With the decreasing cost of digital chips spectrographs with 1000 or more channels and with multi-bit operation have become feasible. Analog to digital converters can now be made cheaply and as a consequence are widely used in receiving equipment. A small computer can then transfer partly reduced data onto a magnetic tape. The discovery of pulsars has brought about the development of many special purpose receiving systems, particularly for de-dispersion applications. One other significant development has been the NRAO Mark II VLB terminal (**21**) which now has been delivered to some 12 users all over the world.

Unfortunately many technical developments are never completely documented or published and duplication of designs often occurs.

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