Orientations Preprints

✓ Guthrie
✓ Legg
✓ Simkin
✓ van den Bergh
Mackay
✓ Schilizzi
✓ Miley
✓ Willis
✓ Christiansen, W.
✓ Blandford
✓ Pacholczyk
✓ Scott, J.
✓ Rees
✓ Gibson
Illingworth
✓ Saslaw
~~[illegible]~~
✓ Baldwin
✓ Scheuer
✓ Broderick
✓ Brolen
✓ Burbidge
✓ Burke
✓ Cannon (Russ)
✓ Fanti
✓ Ekers
✓ Hogbom
✓ Kellermann
✓ Longair
✓ Machalski
✓ Morrison
✓ Palmer
✓ Pooley
✓ Rayburn
✓ Riley
✓ Sargent
✓ Spinrad
✓ Valtonen

✓ van der Laan
✓ Dressel —— REPR.
✓ Wielebinski
✓ M. Davis
Ann Downes
H. Greyber

Royal Observatory, Edinburgh

Director: Professor V. C. Reddish, OBE
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28 May 1979

Dr. Alan H. Bridle,
Department of Physics,
Stirling Hall,
Queen's University,
Kingston,
Canada K7L 3N6.

Dear Dr. Bridle,

Thanks very much for sending me a preprint of your paper on the orientations of radio sources relative to elliptical galaxies. Your results are very interesting, particularly your evidence that the minor-axis trend is stronger for large radio sources.

The good agreement between your measures of the optical orientations and mine is, of course, for some of the favorable cases where the orientations are easily measured. I am now examining the other radio galaxies in your sample on glass copies of the survey plates. I also hope to measure some additional galaxies with recently published radio maps.

With regards,

Yours sincerely,

Bruce Guthrie.

THE ASTROPHYSICAL JOURNAL

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A. DALGARNO, *Letters Editor*
Center for Astrophysics
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March 29, 1979

Dear Dr. Palimaka:

Your paper A PREFERRED ORIENTATION FOR LARGE RADIO SOURCES RELATIVE TO THEIR ELLIPTICAL GALAXIES
has been accepted for publication in THE ASTROPHYSICAL JOURNAL LETTERS and is being forwarded to the Production Office at the University of Chicago Press. The manuscript will be sent to the typesetter one or two days after its receipt by the office. If you have any substantive changes or corrections, please immediately call:

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With thanks for your cooperation, I am,

Yours sincerely,

A. Dalgarno/ws

A. Dalgarno
Letters Editor

Dr. J. John Palimaka
Department of Physics
Queen's University at Kingston
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Canada K7L 3N6

Enclosure

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March 21, 1979

Dr. A. Dalgarno,
Letters Editor,
The Astrophysical Journal,
Center for Astrophysics,
60 Garden Street,
Cambridge, MA 02138

Dear Dr. Dalgarno,

We enclose a shortened version of the paper ´A Preferred Orientation for Large Radio Sources Relative to Their Elliptical Galaxies´ by Palimaka et al., which takes account of the referee´s comments. As we have been able to condense the text by 24%, we ask that it continue to be considered for Part 2 (Letters) rather than Part 1 of the Journal.

We have condensed the paper mostly by giving stricter attention to economies of style. The only losses of information come from shortening the introduction of Sec.IV (we have removed a Table whose main function was to introduce the more detailed analysis which remains in the paper), and from a less detailed discussion of Simkin´s unpublished results at the end of Sec.VI. These excisions do not, in our view, compromise presentation of our main results.

Our responses to the referee´s detailed comments are as follows:

Comment #1: A sentence is added on p.5 giving the typical linear dimensions of the regions we refer to as ´cores´; our usage of the term ´core´ is now strictly limited to this size scale throughout the paper.

Comment #2: The results of Williams and Schwarzschild are included in our cautionary remarks in Sec.I. We cannot comment on the work of Schechter and Gunn, as we have not seen it; this illustrates the problem that preprints may <u>not</u> in fact reach widely enough across traditional discipline boundaries.

Comment #4: We do indeed have evidence that some sources show precessional effects in their structures, but feel that this subject requires more detailed discussion than the context of this Letter permits. We have added a sentence on p.8 noting our intention to address this issue at length elsewhere.

Comment #5: Escape against the mean gravitational field of the galaxy as a whole is governed by the depth of the gravitational potential well in the nucleus rather than by the trajectory of the ejecta. The effect which the referee has in mind must surely be scattering by close encounters with localised masses, which we did in fact refer to as the basis of a possible slingshot interpretation. We have attempted to clarify our original remarks while shortening the paper, but feel that our treatment did in fact already address the referee's point.

Comment #3: This comment goes to the heart of why we seek publication in the Letters rather than in the main Journal. Whether or not our 'major-axis' sources are compatible with beam models depends on the relation between the light distributions and the mass distributions in these particular radio-galaxy cores. If our 'major-axis' sources are in fact on the major axes of the core masses in these galaxies the present beam models might be excluded for these sources. But if the total light in these systems is perturbed by any of the phenomena referred to on p.3 and on p.9 this need not be the case. It is one of our conclusions that optical astronomers should observe our major-axis systems as soon as possible to find the answer to the referee's question. Section VI and Table I of this paper show optical observers which are the key galaxies to observe in order to deal with this most important point; publication in the Letters should be the most effective way of bringing this to the attention of all observers who might be interested in tackling the problem.

As the referee's second comment illustrates, preprints do not always reach people who would be interested in knowing of them, so we hope that our condensation of the paper (and the referee's generally favourable comments) will permit its publication in Part 2 of the Journal. We would greatly appreciate hearing from you as soon as possible if it cannot in fact be accepted for the Letters in its present form.

Yours sincerely

John Palimaka
J.J.Palimaka

Alan H Bridle
A.H.Bridle

G W Brandie
G.W.Brandie

as submitted to Ap. J. Letters
Mar 21/79

A PREFERRED ORIENTATION FOR LARGE RADIO SOURCES RELATIVE TO THEIR ELLIPTICAL GALAXIES

J.J.Palimaka and A.H.Bridle

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*Operated by Associated Universities, Inc. under contract with the National Science Foundation.

I. INTRODUCTION

The relative alignments of powerful radio sources and their parent elliptical galaxies have often been discussed as a test for models of collimation processes and energy transfer in radio galaxies (Mackay 1971; Bridle and Brandie 1973; Gibson 1975; Schilizzi and McAdam 1975; Sullivan and Sinn 1975; Guthrie 1979). From the outset (Mackay 1971; Bridle and Brandie 1973) it was unclear whether radio galaxies should be treated as oblate or prolate rotators. Recently Illingworth (1977) showed that 12 of 13 giant (but not 'radio') ellipticals rotate around their minor axes much more slowly than expected on conventional oblate models, Williams and Schwarzschild (1979) found departures from axial symmetry in two ellipticals, and Binney (1976, 1978) proposed that the forms of elliptical galaxies reflect initial anisotropies in the pregalactic condensations rather than centrifugal flattening.

The relation between light distributions and rotation for radio-emitting ellipticals may be even more complex if their light is perturbed by strong line or nonthermal continuum emission, or (e.g. Saslaw and De Young 1972) by star formation along the radio-source axis. Furthermore, the more distant features of some radio galaxies in rich clusters appear to have been realigned after leaving their parent object. Given these complications, prospects for constraining radio source models by optical-radio orientation studies now appear less attractive than they did in the early 1970s.

We report here what is therefore a surprisingly good correlation between the radio and optical orientations of a carefully-selected sample of elliptical radio galaxies. Our results imply that orientational studies interpreted with much greater circumspection than before may still be useful in evaluating theories of radio galaxies.

II. OBSERVATIONS

In 1973 we compiled a list of over 1100 radio sources purportedly identified with elliptical galaxies, and searched the fields of these sources print distortions (whatever their cause), and all galaxies whose images on the Sky Atlas show significant asymmetries. We also defer discussion of galaxies with noticeable concentrations of dust or with multiple nuclei, and those classified by us as S0, to a later paper.

Each optical position angle was measured independently by several observers. Where both a diffuse 'envelope' and a more compact (often burned-out) 'core' were distinguishable, both position angles were recorded but the core position angles form our primary data. These 'cores' are typically 10-20 kpc in diameter.

The standard deviation of all otherwise acceptable E-print measurements is 7°; that of all acceptable radio position angles is 4°. Any galaxy for which the combined optical and radio position-angle errors are $>20^{\circ}$ was rejected. Only 70 'clean' elliptical galaxies with well-collimated radio sources met these and all preceding criteria. Because of this severe attrition from our original sample we supplemented our data with radio maps published since 1973, adding a further 8 well-identified radio galaxies which meet all of our criteria.

III. THE OVERALL DISTRIBUTION OF RELATIVE ORIENTATIONS

Table I lists our data for the 78 radio galaxies which survived our selection process. The largest linear size (LLS) of each radio source (estimated from the 20% peak brightness contours of its extended structure) and the 2.7-GHz monochromatic luminosity ($P_{2.7}$), were computed for $H_0 = 50$ $km.s^{-1}.Mpc^{-1}$ and $q_0 = 0.5$; if the redshift of a galaxy was unknown it was estimated from the apparent magnitude as in Bridle and Fomalont (1978).

Figure 1 shows the overall distribution of the 78 position-angle differences (optical major axis minus radio collimation axis). The shaded distribution is derived from 40 'well-ordered' galaxies whose O-print images do not show blue subsystems which are significantly misaligned with the measured red images, and whose 'core' and 'envelope' position angles agree on the E print.

V. COMPARISON WITH EARLIER RESULTS

The results shown in Table II partially explain why the 'minor-axis' trend was not found by Mackay (1971), Bridle and Brandie (1973), Gibson (1975) or Sullivan and Sinn (1975). Their samples contained few radio sources with linear sizes >250 kpc, so were drawn from a population with only a weak minor-axis preference. In addition, we rejected many galaxies studied by these authors on grounds of optical asymmetries, jets, or faintness. The samples used by Schilizzi and McAdam (1975) and Guthrie (1979) contain a higher proportion of large sources, and the minor-axis trend did indeed begin to appear in these authors' results.

VI. DISCUSSION

Recent high-resolution studies of radio galaxies (Northover 1973; Burch 1977; van Breugel and Miley 1977; Waggett et al. 1977; Bridle et al. 1979) show that bright collimated jets of emission connect the active nuclei of some radio galaxies to their distant radio lobes. These observations favour source models in which relativistic particles and magnetic fields are supplied to the lobes by relativistic beams (Blandford and Rees 1974; Benford 1978) or plasmon streams (Christiansen et al. 1977) that suffer radiative losses at radio frequencies. Our results have a consistent (if not unique) interpretation in terms of such models.

If the proposed relativistic beams or plasmon streams are collimated by flattened mass distributions in galactic nuclei (as in the model of Blandford and Rees 1974), our results imply that the shortest dimensions of these collimating masses are preferentially within ~30° of the minor axes of the stellar distributions in the inner ~15 kpc of their galaxies. This would be dynamically plausible if most radio-galaxy cores rotate as oblate or nearly-oblate systems so that the minor axis of their light is near the axis of their net angular momentum.

radio emission near their major axes ($0-15^{\circ}$ bin), and to distinguish whether these alignments are due to prolate stellar systems or to enhancement of the total light along the path of energy supply to the radio lobes, e.g. by nonthermal emission, by strong emission lines from shocked gas, or by stimulated star formation.

Since this work was completed, we learned of new observations of the rotations of five radio galaxies by Simkin (private communication). She finds their rotation axes to be directed near, but not exactly towards, the brighter features of their radio lobes. Her result is consistent with ours if the inner ~15 kpc regions of most large radio galaxies are indeed oblate rotators.

ACKNOWLEDGMENTS

We thank Dr B.Guindon and Mr R.W.Scholes for their assistance with the inspections of the Palomar Sky Atlas, and Dr B.N.Guthrie and Dr S.M.Simkin for supplying results in advance of publication. JJP acknowledges financial assistance provided by a Queen's Graduate Fellowship and a Carl Reinhardt Fellowship. This research was partially supported by grants to AHB from the National Research Council of Canada and the Advisory Research Committee of Queen's University.

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Waggett,P.C., Warner,P.J. and Baldwin,J.E. 1977, M.N.R.A.S., **181**, 465.

Williams,T.B. and Schwarzschild,M. 1979, Ap.J., **227**, 56.

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National Radio Astronomy Observatory, P.O. Box 2, Green Bank, W.Va. 24944

TABLE I

Optical and Radio Position Angle Data

Field Name	Optical P.A. (E print)	Radio P.A.	Relative P.A.	LLS (kpc)	$\log P_{2.7}$ (W Hz^{-1})
0018-194	17°	111°	86°	1100	25.86
*0034+254	163	83	80	110	23.21
0043+201	69	172	77	330	25.20
*0055+300	42	129	87	1400	24.23
*0055+265	152	109	43	230	25.02
*0104+321	135	147	12	170	24.64
0106+130	131	20	69	430	26.05
0108-142	53	100	47	120	25.08
0109+492	101	9	88	950	25.39
*0124+189	76	13	63	71	24.89
0153+053	73	84	11	45	23.90
*0220+427	33	50	17	210	25.02
*0300+162	134	110	24	95	24.93
*0305+039	144	56	88	48	25.25
0325+023	153	63	90	200	25.07
0326+396	128	82	46	220	24.24
0331+391	101	180	79	14	24.10
0356+102	72	25	47	230	25.34
*0632+263	16	115	81	110	24.57
*0652+426	124	50	74	69	24.89
*0712+534	120	114	6	39	24.84
0714+286	73	133	60	110	25.24
0734+806	49	150	79	540	26.10
*0745+521	37	92	55	200	24.72
0802+243	13	118	75	310	25.69
*0818+472	103	4	81	51	25.88
0819+061	98	38	60	570	25.44
*0836+299	59	27	32	78	24.91
0844+540	45	113	68	58	25.00
0844+319	123	170	47	540	25.15
0915+320	46	31	15	470	24.57
0936+361	118	164	46	980	26.23
0938+399	45	15	30	230	25.80
*1000+201	112	8	76	150	25.91
*1003+351	45	123	78	5800	26.19
1005+007	38	71	33	26	24.90
1033+003	131	8	57	300	24.81
1102+304	147	70	77	260	24.74
*1113+295	138	71	67	110	25.13

TABLE I (Cont.)

Optical and Radio Position Angle Data

Field Name	Optical P.A. (E print)	Radio P.A.	Relative P.A.	LLS (kpc)	$\log P_{2.7}$ ($W\ Hz^{-1}$)
*1122+390	35°	118°	83°	6	22.28
1127+012	100	12	88	140	25.51
*1137+123	139	12	53	140	25.08
*1154-038	45	109	64	400	24.43
*1216+061	150	83	67	100	24.39
*1222+131	116	167	51	12	23.17
*1249+035	27	146	61	150	25.15
1250-102	65	162	83	35	23.72
1251+278	30	169	41	97	25.79
*1254+277	51	11	40	23	23.00
*1313+072	40	71	31	200	25.21
*1318-434	100	24	76	550	24.87
*1322+366	75	7	68	23	23.92
*1333-337	47	125	78	780	24.65
*1358-113	41	125	84	260	24.56
*1407+177	6	73	67	250	24.13
*1411+094	84	178	86	260	26.11
*1414+110	146	85	61	200	24.77
1422+268	118	96	22	120	24.49
1433+553	110	143	33	230	25.36
1449-129	135	89	46	720	25.81
*1514+004	53	132	79	390	25.27
1514+072	21	16	5	43	25.05
1547+309	136	120	16	46	25.54
1553+245	19	129	70	23	24.11
*1602+178	117	171	54	74	24.52
*1640+826	27	124	83	2800	24.91
1710+156	5	169	16	19	25.14
1759+211	60	50	10	200	25.21
*1833+326	73	48	25	420	25.73
1833+653	97	19	78	38	26.15
*1834+197	22	142	60	210	24.12
*1940+504	34	28	6	37	24.48
2058-135	29	101	72	340	24.49
2103+124	59	138	79	260	25.49
2116+262	65	22	43	23	23.15
*2117+605	106	35	71	140	25.80
*2229+391	7	9	2	170	24.30
2354+471	52	64	12	180	24.64

* Members of the well-ordered sample.

TABLE II

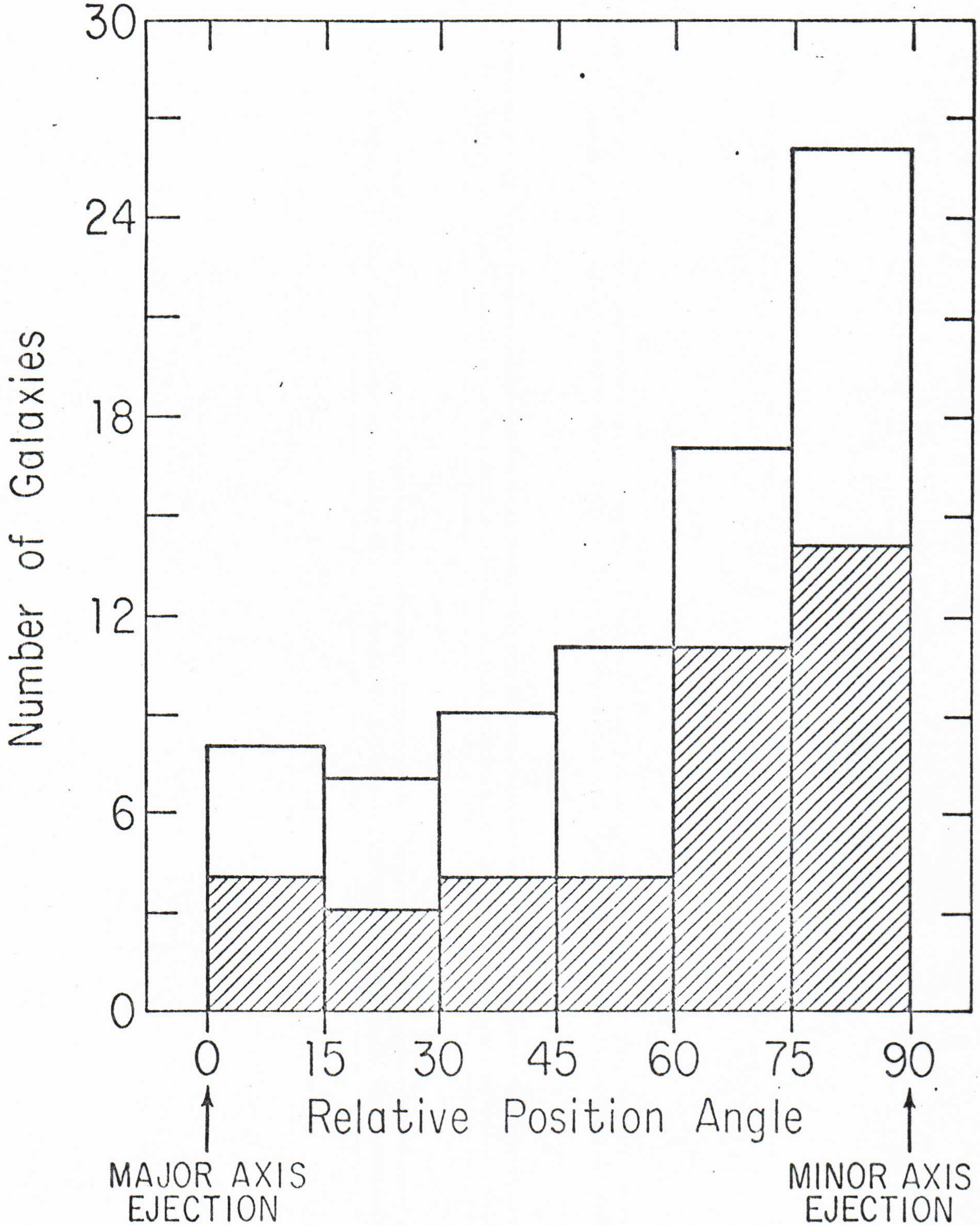
Distributions of Relative Position Angle Within Selected Ranges of Linear Size and Monochromatic Luminosity

	(a) LLS (kpc)				
Relative P.A.	≤ 40	≤ 102	102–250	≥ 250	≥ 450
0–30°	3	7	6	2	1
30–60°	4	7	9	4	3
60–90°	6	12	11	20	9
$P(>\chi^2)$		38%	48%	0.001%	

	(b) $P_{2.7}$ (10^{25} W Hz^{-1})				
Relative P.A.	≤ 0.17	≤ 0.44	0.44–1.62	≥ 1.62	≥ 6.00
0–30°	1	7	6	2	0
30–60°	3	5	8	7	4
60–90°	9	14	12	17	9
$P(>\chi^2)$		7.6%	34%	0.12%	

FIGURE CAPTION

Fig. 1. The distribution of relative position angle |Radio-Optical| for the sample of 78 radio galaxies. The shading indicates the distribution of the well-ordered sample.



30
24
18
12
6
0
Number of Galaxies
0
15
30
45
60
75
90
Relative Position Angle
MAJOR AXIS
EJECTION
MINOR AXIS
EJECTION

THE ASTROPHYSICAL JOURNAL

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March 9, 1979

Dr. J. John Palimaka
Department of Physics
Stirling Hall
Queen's University at Kingston
Ontario, Canada K7L 3N6

Dear Dr. Palimaka:

I enclose a copy of the referee's report on your paper, A PREFERRED ORIENTATION FOR LARGE RADIO SOURCES RELATIVE TO THEIR ELLIPTICAL GALAXIES. If you are willing to revise your paper in the light of these remarks, I shall be happy to accept it for publication in Part I of the Astrophysical Journal.

Yours sincerely,

A. Dalgarno/nd

A. Dalgarno
Letters Editor

AD:nd
Enclosures

Published by The University of Chicago Press, 5801 Ellis Avenue, Chicago, Illinois 60637
for THE AMERICAN ASTRONOMICAL SOCIETY

This is the best work done so far on the subject of the alignment of radio lobes and the axis of their central galaxy. Both the quality and quantity of the observations go significantly beyond previous work and should certainly be published in the Ap. J. Although it is a bit too long for the Letters, it is written concisely and well and it is difficult to see how it could be condensed without leaving out important information. The topic is an important one. Either the Letters or the main Journal would be suitable. Perhaps the main Journal would be more appropriate since the results do not seem to lead to a definitive conclusion regarding radio source mechanisms, and the number of people working in this particular area of the subject is small enough to be reached by several preprints.

In any case, there are some improvements which should be made before the paper is published:

1. The meaning of "core" in the abstract and throughout the paper should be clarified. There are at least four length scales involved in the problem: the innermost region of the nucleus ($\sim 10^{-2}$ pc) where the energy is generated, the nucleus (~ 1 - 10 pc) where the energy is channeled or deflected, the central region ($\sim$ 1-10 kpc) of the galaxy which may also channel the energy and whose ellipticity has been measured, and the scale of the main radio emission ($\gtrsim 50$ kpc). "Core" could apply to more than one of the first three in different parts of the paper. It would help to be more explicit.

2. Page 3: There is increasing evidence (e.g. Williams and Schwarzschild Ap.J. 227,56; Schechter and Gunn, in press) that elliptical galaxies are neither oblate nor prolate, but triaxial or more complex. This will alter the projection effects considerably and should be included as a further reason for caution.

see p.9 3. Page 10: Are those cases with ejection along the major axis inconsistent with beam models? None of the beam models seem to predict such ejection and perhaps this should be mentioned.

4. Page 11: If beam models precess in the way described here, one should expect to see some evidence of precession in the structure of the sources. This should especially show up in the sources not aligned with the minor axis since they would precess more. Is there any systematic tendency in the observations showing this effect?

5. Page 11-12: In the slingshot model, would not escape against the galaxy's gravitational field be easier along the minor axis of the central region? Thus if the ejection mechanism were fairly randomly oriented in the innermost region, the objects escaping along the minor axis of the galaxy would, on average, retain higher velocity and form the larger linear size sources. This would also lead simply to the observed correlation.

In summary, I think this paper should be published after taking the above comments into account. It is basically a very good piece of work.

(Please type your report on this sheet. Use other side if necessary.)

THE ASTROPHYSICAL JOURNAL

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February 26, 1979

Dr. J. John Palimaka
Department of Physics
Stirling Hall
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Ontario
Canada K7L 3N6

Dear Dr. Palimaka:

We have received your paper, A PREFERRED ORIENTATION FOR LARGE RADIO SOURCES RELATIVE TO THEIR ELLIPTICAL GALAXIES, and have sent it to a referee. It will be necessary for you to prepare a shorter version consistent with our page limit for the Letters, but you may want to wait for the referee's comments before preparing this abbreviated version. We estimate that the present length of your manuscript would comprise 5 journal pages and thus will need to be shortened by approximately 20%.

Yours sincerely,

A. Dalgarno /ao

A. Dalgarno
Letters Editor

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February 20, 1979

Dr. A. Dalgarno
Letters Editor
The Astrophysical Journal
Center for Astrophysics
60 Garden Street
Cambridge, Mass. 02138

Dear Dr. Dalgarno:

Enclosed are three copies of the manuscript "A Preferred Orientation for Large Radio Sources Relative to their Elliptical Galaxies", by J. J. Palimaka, A. H. Bridle, E. B. Fomalont and G. W. Brandie, for consideration as an article in the Astrophysical Journal, Letters to the Editor. Two glossy reproductions of Figure 1 are also enclosed.

Please send all correspondence to:

J. John Palimaka
Dept. of Physics, Stirling Hall
Queen's University at Kingston
Ontario, Canada
K7L 3N6

Sincerely yours,

John Palimaka

JJP/bbs
Encls.

Fig I data

	The Sample of 78	The Sample of 40	The "Disordered" 38
0-15	8	4	4
15-30	7	3	4
30-45	9	4	5
45-60	11	4	7
60-75	17	11	6
75-90	26	14	12
	78		

$\chi_s^2 = 20.46$ (Sample of 78)

$\chi_s^2 = 16.10$ (Sample of 40 / "Disordered" 38)

Sample of 78:

	86^{+28}_{-21}	24.63 ± 0.15
	224^{+81}_{-60}	25.04 ± 0.19

	$\overline{LLS}$	$\overline{P_{2.7}}$
0°-15°	80^{+44}_{-28}	24.56 ± 0.11
75°-90°	261^{+159}_{-100}	24.85 ± 0.30

Table II data

	$\overline{LLS}$ (kpc)	$\log_{10} \overline{P_{2.7}}$ ($W.Hz^{-1}$)
0°-15°	86^{+28}_{-21}	24.63 ± 0.15
75°-90°	224^{+81}_{-60}	25.04 ± 0.19

Table III data

(a)

LLS (kpc)	≤40	≤102	102–250	≥250	≥450
0°–30°	3	7 (6)	6 (5)	2 (4) [4.3]	1
30°–60°	4	7 (6)	9 (7)	4 (7) [7.0]	3
60°–90°	6	12 (14)	11 (15)	20 (15) [14.7]	9
$P(>\chi^2)$		98% $\chi^2=1.9$	48% $\chi^2=1.5$	0.001% $\chi^2=22.5$	$\chi^2=4.42$

(b)

$P_{2.7}$ (W Hz^{-1})	$\leq 1.70\times10^{24}$	$\leq 4.42\times10^{24}$	$4.42\times10^{24}-1.62\times10^{25}$	$\geq 1.62\times10^{25}$	$\geq 6.00\times10^{25}$
0–30	1	7 (6)	6 (5)	2 (4)	0
30–60	3	5 (7)	8 (7)	7 (6)	4
60–90	9	14 (13)	12 (14)	17 (16)	9
$P(>\chi^2)$		7.6% $\chi^2=5.2$	34% $\chi^2=2.2$	0.12% $\chi^2=13.5$	

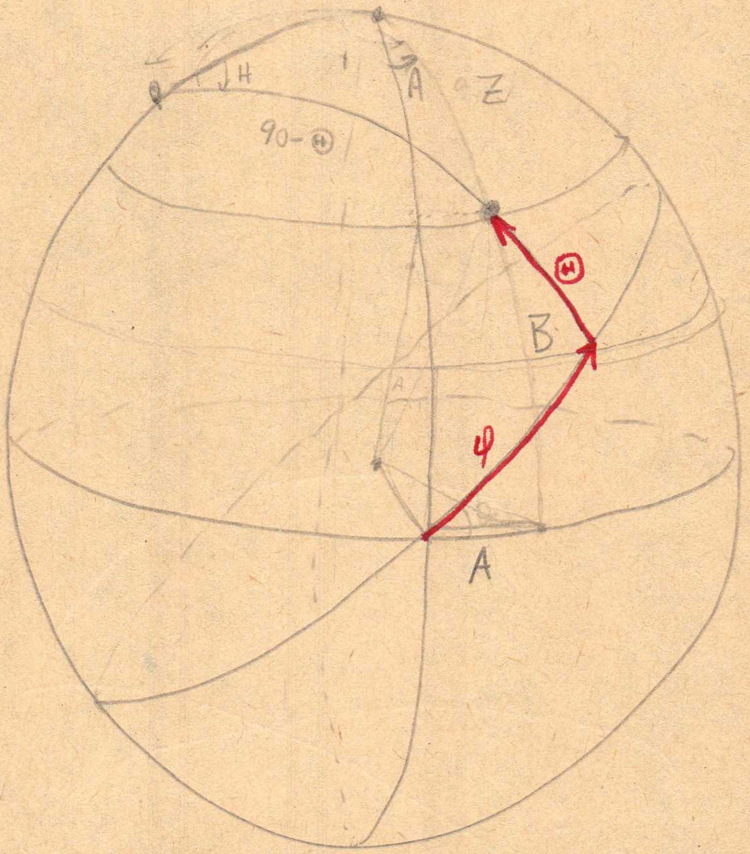
High vs. low luminosity (26) 8.2%

Large vs small size (26) 0.6%

↓ for internal use only.

The 13 largest gals with (LLS ≥450 kpc) are all but one in 45°–90° (8 in 75–90°), while the 13 smallest (LLS ≤ 40 kpc) are random; whereas the 13 faintest (logP < 24.23) ~~are (1, 3, 9)~~ and ~~show the effect~~. the 13 brightest (logP ≥ 25.75) show the effect.

ϑ



$$\sin B = \sin \Theta \cos \vartheta + \cos \Theta \sin \vartheta \sin \varphi$$

$$\cos B \cos A = \cos \Theta \cos \varphi$$

$$\cos B \sin A = -\sin \Theta \sin \vartheta + \cos \Theta \cos \vartheta \sin \varphi$$

$$\tan \Phi = \frac{\sin B}{\cos B \cos A} = \frac{\sin \Theta \cos \vartheta + \cos \Theta \sin \vartheta \sin \varphi}{\cos \Theta \cos \varphi}$$

$$= \tan \Theta \frac{\cos \vartheta}{\cos \varphi} + \sin \vartheta \tan \varphi$$

Now $$\boxed{\tan \Phi = \tan\phi \sin\theta + \tan\Theta \cos\theta \sec\phi}$$

~~$\sec^2\Phi \, d\Phi = \sec^2\phi \, d\phi \sin\theta$ as before~~

Let galaxy axis be tipped by θ towards observer.

i.e. $\theta = 0 \rightarrow$ galaxy rotation axis in plane of sky.

Observed Galaxy axial ratio is $r = \sqrt{\dfrac{\tan^2\theta + b^2/a^2}{\tan^2\theta + 1}}$

Frequency distribution of θ is $N(\theta)\,d\theta = \cos\theta\,d\theta$

Projection of radio source.

Suppose that source emerges at random nucleocentric longitude ϕ in galactic plane, as before, but at [redacted] a galactic nucleoc. latitude Θ

Then the projected galaxy - source position angle,

formerly $\tan\Phi = \tan\phi\sin\theta$

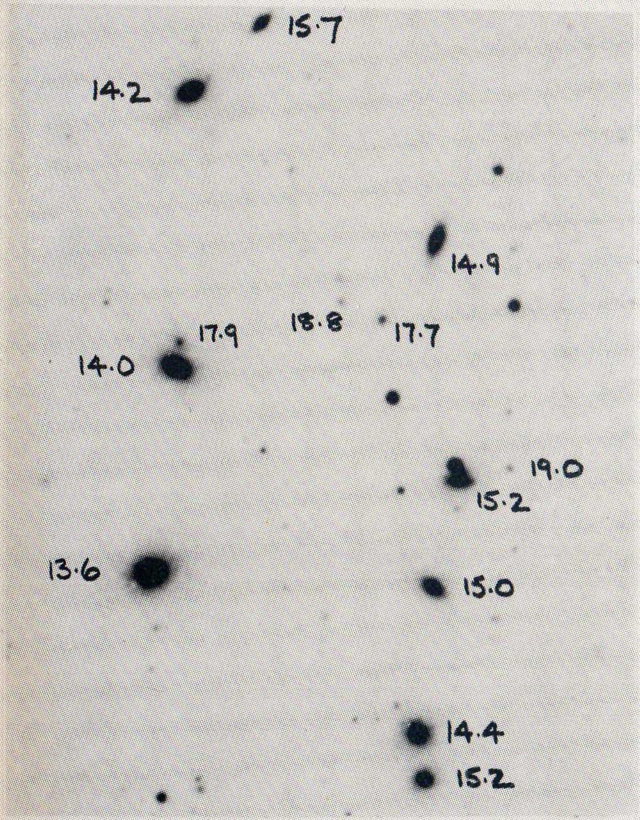
is now $\tan\Phi = \tan\phi\sin\theta + \tan\Theta\cos\theta\sec\phi$

Distribution of ϕ is uniform $0 \rightarrow 2\pi$

~~Distribution of Θ is ... $N(\Theta) = \cos\Theta\,d\Theta$~~

Distribution of Θ is $N(\Theta) = \cos\Theta\,d\Theta$

~~$N(\Phi)\,d\Phi$~~$) =$



VISUAL STANDARDS

Coma Cluster