From: CVAX::ABRIDLE   14-SEP-1990 10:58
To: EFOMALONT,ABRIDLE
Subj: Possible changes to 0326 paper

Suggested changes to 0326 paper based on referee's verbal comments (AHB):
~~~~~~

*** page and line numbers are from Paola's submitted version ***

on p.4, line 9   "galaxy UGC 2755 (VV 7.08.14)". ✓

on page 7, line 7   for "antisymmetric", put "{\bf S}-symmetric" ✓

on p.11, line 9. "Both the CLEAN (Figures 9 and 10a) and MEM deconvolutions (Figure 10b) show that, beyond this brightest feature, the ridge line of the jet deflects to the south then oscillates around a mean position angle of -92.3. The oscillation "wavelength" is ill-defined, but of order 2.5". Note that the region shown in Figure 10 is about as long (in projection) as the entire one-sided optical/radio jet in M87 (Virgo A), which shows a similar sequence of features." ✓

p.15, l.8 add "necessarily" before "exhibits"

page 18:
Figure 18(c) has been regenerated as a laser printer plot and I am shipping its QMS plot file to Paola by E-mail. We can either combine it with the existing panels in a 3-panel Figure (as implied by the text), or drop it and the text (we don't refer to the result again later). Adding panel (c) properly to the Figure will imply some delay in our graphics NRAO queue again. I'm not sure it's worth the effort!

p.19, line 1 Figures 18(a) and 18(b) also both show ....

p.29, line 12 These estimates of v_j cannot be taken as rigorous upper limits, however. The underlying assumption of equipartition is questionable. The apparent spectral gradients also depend on resolution and are not monotonic, as they would be if they were produced entirely by spectral ageing. These estimates do illustrate, however, that relatively low velocities are consistent with [explaining] the larger spectral gradients in this jet ....

(N.B. we should drop the italics on "upper limits"; the referee felt that they overemphasized the upper limit given the above caveats and the fact that we throw it away later!)

p.36, line 19, add to end of paragraph:

Our estimates of jet velocity and Mach number imply sound speeds in the jet of 250 h^{-4/7} \kappa^{-1} km/s near \Theta = 10" and 18 h^{-4/7} \kappa^{-1} km/s near \Theta = 100". In ionized hydrogen and with \kappa = 0.04, these correspond to temperatures of 1.8 x 10^9 h^{-8/7} K and 9.4 x 10^6 h^{-8/7} K respectively. The inner jet may therefore be closer to the regime in which the correction for the thermal energy is significant. [km.s^-1] – Keep new para after this sent.

p.37, line 3
The apparent complexity of the spectral index structure in this jet casts some doubt on the velocity estimates from spectral ageing,
~~~~~~

while the lack of depolarization and RM structure in the outer jet argues strongly against high values of \kappa or magnetic fields that are much stronger than their equipartition values. Because of the discrepancies between the spectral indices we obtained at different resolutions (see Figures 17 and 20), we give greater weight to the higher velocities derived from the energy budget.

In Table 5:
rms noise on VLA 0.6 x 0.6 image is 40 microJy/beam, not 10
footnote: the rms noise in the 6" x 10" data at 1.465 GHz is dominated by responses to a confusing source to the south-west; the rms is therefore given separately for the East (E) and West (W) halves of the field.

From: CVAX::ABRIDLE 5-APR-1990 11:00
To: ASTB01::PAOLINA,ABRIDLE
Subj: RM statistics around 0326

Paola, I've realised that I completely forgot to put the RM statistics into the draft that I sent you. I also had a couple of questions about your E-mail message in January. So here goes ...

In your message you said that you had searched out to 10 degrees from 0326, but two of the sources you sent (3C68.2 and 4C29.08) appear to be over 13 degrees away from the galactic coordinates you gave for 0326. Did you search out to 15 degree rather than 10, by any chance? Also, Simard-Normandin and Kronberg give RMS for two other sources at similar distances from 0326 - 3C68.1 (l = -145.6, b = -24.0, RM = -63 +/- 2) and 3C91 (l = 147.8, b = -3.9, RM = -136 +/- 1). All of this says that the RMs of other sources around 0326 are indeed highly dispersed, so does not change your conclusion, of course.

Shall we add to the fourth paragraph of Section 6.4:

"It is int clear, however, whether the Faraday screen is associated with
not
the radio galaxy or with the foreground medium of our galaxy. B2 0326+39 is at l=153.1, b=-13.6, a region in which the rotation measures of other extragalactic sources show considerable dispersion. The RMs of ten other extragalactic sources within 15 degrees of B2 0326+39 range from -136 rad m^-2 to +339 rad m^-2 and their median is beteen 18 rad m^-2 and 29 rad m^-2."

This then squares with the statement in the abstract about not being able to tell where the screen is (which we neglected to make in this Section of the paper itself!).

Finally, in your message on 18 January you said that Section 6.4 was in the wrong place. I didn't think it was (Section 6 is supposed to be all the lobe properties) so am I missing something important?

Sorry I left this out, I simply mis-sorted your January message in the pile I have for 0326 and didn't uncover the omission until today!

Cheers, Alan

From: CVAX::ABRIDLE   11-DEC-1989 14:54
To: 38057::PAOLINA,ABRIDLE
Subj: RE: 0326+39

Hello again Paola. I hope you got back o.k. despite the storm.

I just talked again with Phil Hardee about the differences between his formulae with the 1+sqrt(eta) and 0.66+sqrt(eta) in the denominator for the spatial-domain analysis. He says the 0.66 was a better fit to the curves for high Mach numbers, but that at low Mach numbers the wavelengths do indeed get shorter than this analytic form predicts. So it may be best to use the formula he gave in 1984, which is better for lower Mach numbers but still gives a longer wavelength than pure time-domain analysis. Phil also suggested that we say that something like a +/- 50% range in the Mach number is consistent with the uncertainties in this business for the lower Mach numbers. I'll put some words in to that effect.

It was good to see you again, and I hope we really are close to being done this time. When I looked again at the business of RM gradients, I wasn't too keen on saying much about lobe-to-lobe differences as Stefi suggested, because of the ambiguities and the remaining differences between the VLA and WSRT "answers". But it might be interesting to say whether one lobe or the other has a mean RM that is closer to the mean of nearby sources. You thought you would already have the nearby-source RM statistics -- let me know if you do, and perhaps suggest what you would like the paper to say about this.

Best wishes, Alan

From: ASTBO1::PAOLINA 18-JAN-1990 04:00
To: 6654::ABRIDLE
Subj:

Dear Alan,
I am just back to work, after having been one of the many victims of the flu.
I agree with you that we shouldn't say much about the lobe RM differences.
Reading the last version of the paper I noticed that the paragraph on the lobe rotation measure(#6.4) is not in the right section and also that the values of RM for the east lobe are completely missing. Any reason for that? } ?
I have redone the nearby source RM statistics. Here is the list of sources present in an area of 15 degrees of radius centered on 0326+39

name	l	b	RM rad/m2	
0326+39	153.1	-13.6		
0314+416 ✓	150.1	-13.1	18 +- 1	✓
3c84 ✓	150.6	-13.3	242 +- 18	
3c93.1 ✓	160.0	-15.9	339 +- 9	
NRAO140 ✓	150.0	-18.8	58 1	✓ SK
3c103 ✓	156.8	-6.6	- 42 1	✓
3c68.2	147.3	-26.4 ?	16 3	✓
4c29.08	150.6	-27.3 ?	- 60 5	✓
4c34.13 ✓	154.1	-19.3	29 3	✓

Excluding the two sources with very high RM we have a mean of ~ 3 rad/m2 with a very high dispersion. Everything remains uncertain as before.
Best wishes, Paola

3C68.1 ✓ 145.6 -24.0 -63 2
[illegible]
3C91 ✓ 147.8 -3.9 -136 1

Table 8b. Physical parameters of the broad components

Radio luminosity at 1.4 GHz	$2.8 \cdot 10^{23}$ W Hz^{-1}
Component sizes	36 x 44 Kpc
Equipartition energy density	$6 \cdot 10^{-13}$ erg cm^{-3}
Equipartition energy	$5 \cdot 10^{56}$ erg
H_{eq}	$2 \cdot 10^{-6}$ gauss
n_e	$3 \cdot 10^{-4}$ cm^{-3}
Thermal plasma mass	$2 \cdot 10^{+8}$ $M_\odot$
Alfven velocity	330 Km/sec

Fig 4

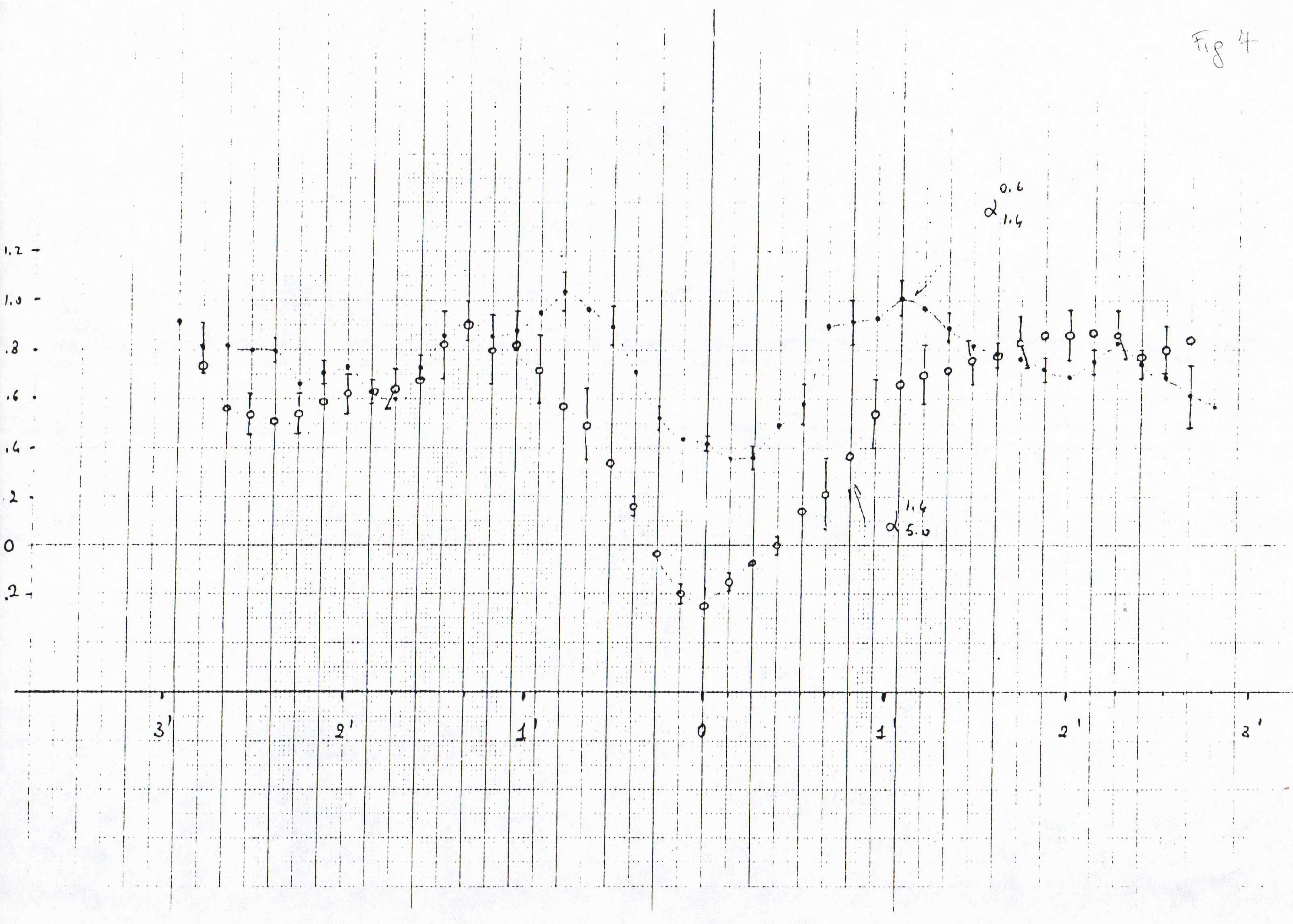

Table 7. Polarization parameters of the lobes.

	Eastern lobe	Western lobe
21 - 6	-5	60
50 - 21	~ 0 + 10	~ 70 + 30
Dep.Ratio(50/21)	~ 0.2	~ 0.4
(R.M.)i rad/sq.m.	~ 11	~ 8

Table 5. Total intensity parameters of the lobes.

	Eastern lobe	Western lobe
Flux at 5.0 GHz	160 mJy	125 mJy
" " 1.4 "	530 "	510 "
" " 0.6 "	1130 "	1070 "
Spectral index	0.95	1.05
Angular size	120"x 80"	120"x 80"

Table 6. Polarization parameters of the Central component.

		Central component (core subtracted)		Core	
5 GHz	%	10(E)	18(W)	2	
	deg	102 "	101 "	20	
1.4	%	16 "	20 "		
	deg	112 "	120 "		
0.6	%	3 "	5 "		
	deg	-60 "	25 "		
(R.M.) rad/sq.m.		2 "	8 "		(from rotation angle)
$(R.M.)_i$		~ 10			(from depolarization)

Table 3. WSRT map parameters.

Frequency GHz	HWHM arcsec	Int. Spacings sh./incr./long. wavelengths	R.M.S. noise mJy	Off-set zero lev. mJy
5.0	6 x 10	900/600/26690	0.5	- 0.2
5.0	26 x 41	900/600/6900	0.8	- 0.5
1.4	26 x 41	857/343/6686	0.8	- 1.7
1.4	26 x 41	172/343/6686	0.8	- 1.5
1.4	51 x 80	172/343/3257	1.6	- 0.5
0.6	26 x 41		1.2 I 0.5 U,Q	- -
0.6	51 x 80	110/147/3269	2.7	-

VLA map parameters

		Taper	mJy	Mean offset zero level mJy	Zero sp.
1.465	6x10	56x14 kλ	I ~~320~~ 3~~2~~0 E/420 W Q U 130/130	+ 200 ?	1.80
1.465	4x4	72 kλ	I 160 Q/U 95	+40 ?	1.80
4.885	6 x 10	22x15 kλ	IQU 130	+ 60 ?	0.58
4.885	4x4	37x42 kλ	IQU 70	23 ?	0.58
4.885	2x2	100 kλ	IQU 45	-5	0.58
4.885	0."6x0."6	none	IQU 45	+10	0.58

Table 4a. Core parameters.

		VLA
R.A.	03 26 06.7	03 26 06.50
Dec	39 37 16.4	39 37 14.0
Flux density at 1.4 GHz (VLA) *	50 mJy	50
" " " 5.0 " (WSRT)	98 "	78
Spectral index	− 0.55	
Angular size	< 3 x < 5 arcsec	
Radio Luminosity at 1.4 Ghz	3.6 x 10E22 W/Hz	

~~* Fomalont, private comunication~~

Table 4b. Jet parameters

Total flux at 5.0 Ghz		250 mJy
Maximum length		+ 2.9 arcmin
Transverse size	at 18"	< 5 arcsec
Brightness		> .25 mJy/sq.arcsec
Transverse size	at 90"	~ 20 arcsec
Brightness		.02 mJy/sq.arcsec
Spectral index		~ 0.3 + 0.1

$$\frac{418.78-37.67}{37.67} = \Delta\lambda_{6\to20} = 0.0988\ \Delta\lambda_{6\to20}.$$

Table 8a. Physical parameters of the jet

Radio luminosity at 5.0 GHz		1.5×10^{23} W Hz^{-1} → 7.3×10^{22} jet (114 mJy)
Linear size		± 63 Kpc
Transverse size	at ± 6.5 Kpc	< 1.8 "
	at ±33 "	~7.0 "
Heq	at ± 6.5 Kpc	$>10^{-5}$ gauss
	at ±33 "	$\simeq 3.7 \cdot 10^{-6}$ "
n_i (at ± 6.5 Kpc)		$\sim 3 \cdot 10^{-3}$ cm^{-3}
Alfven velocity		370 Km/sec

Table 8b. Physical parameters of the broad components

Radio luminosity at 1.4 GHz	$2.8 \cdot 10^{23}$ W Hz^{-1}
Component sizes	36 x 44 Kpc
Equipartition energy density	$6 \cdot 10^{-13}$ erg cm^{-3}
Equipartition energy	$5 \cdot 10^{56}$ erg
H_{eq}	$2 \cdot 10^{-6}$ gauss
n_e	$3 \cdot 10^{-4}$ cm^{-3}
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" " 0.6 "	1130 "	1070 "
Spectral index	0.95	1.05
Angular size	120"x 80"	120"x 80"

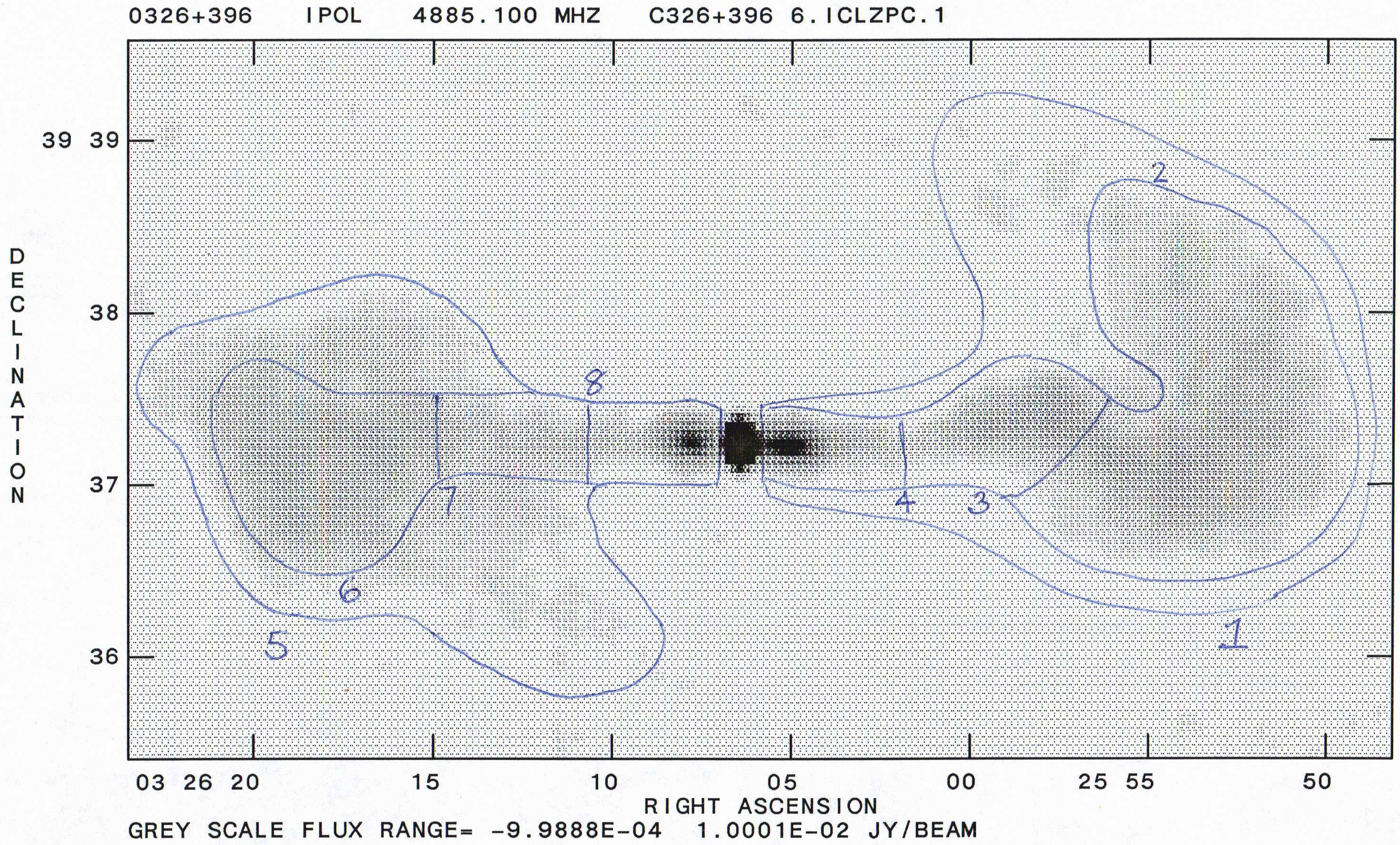
Table 7. Polarization parameters of the lobes.

	Eastern lobe	Western lobe
21 - 6	-5	60
50 - 21	~ 0 + 10	~ 70 + 30
Dep.Ratio(50/21)	~ 0.2	~ 0.4
(R.M.)i rad/sq.m.	~ 11	~ 8

5 = 194 mJy
6 = 119 mJy
7 = 50 mJy
8 = 34 mJy

Integrated Flux Densities

1 = 200mJy ±20
2 = 194mJy ±10
3 = 76 mJy ± 6
4 = 39 mJy ±2



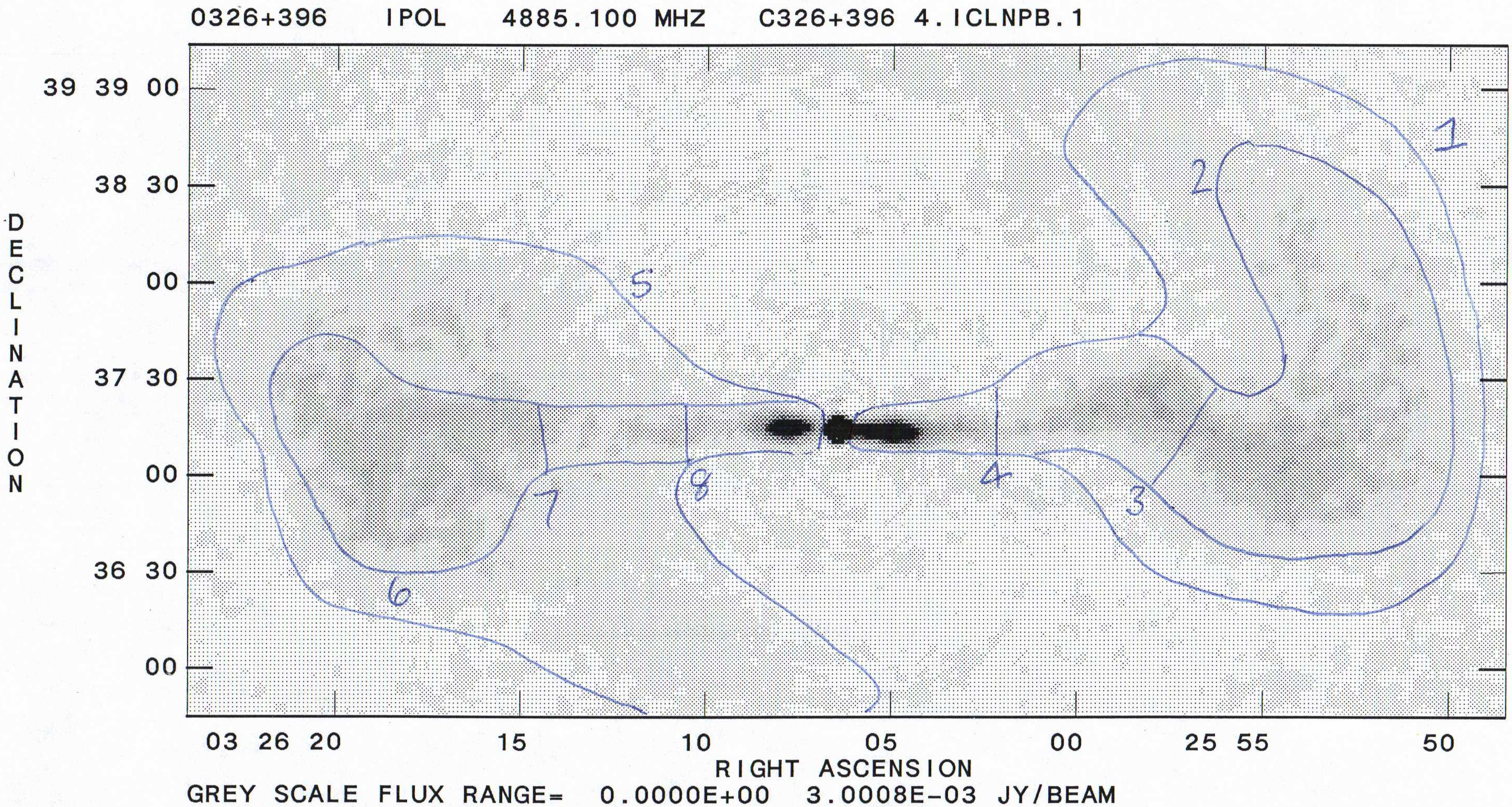
Total integ on map = 489 mJy ±10

4 → pixel 340 offset 1′

5 = 225 ± 10 mJy
6 = 140 ± 5 mJy
7 = 48 ± 2 mJy
8 = 32 ± 1 mJy

Integrated Flux Densities

1 = 240 mJy ± 10
2 = 220 ± 10
3 = 85 ± 5
4 = 43 ± 1



Total integ. on map 556 ± 10 mJy.

Dear Alan,
some comments on the 0326+39 draft:

- I don't think we can say more on lobe polarimetry since the data are so uncertain ; the lobe magnetic field configuration is similar to that proposed by Laing (1980) (sphere model) but due the uncertainties of the polarization data I don't know if it is worth to do numerical simulations in order to look at the depolarization properties.

I have plotted depolarization against total intensity for the lobes to see how different they are; it is confirmed that the two lobes differ significantly in their patterns of depolarization only if we consider the brightest part of the lobe (see plot).

I agree that it is better not to estimate sound or Alfven speeds since ne upper limits are not secure.

Assume 2, see Mj?

- Wiggles

The biggest problem in using Blandford/Icke analysis is that the wiggles are asymmetric, one big wiggle on one side only; if instead we use Hardee or Ferrari analysis, although made for high Mach number, we find in both cases $\rho_{int}/\rho_{ext} \simeq$ 0.01, the density ratio needed in the Bicknell's model (using a Mach number of 2-3 and λ / R ~ 5 -10).

- jet velocity

I have estimated jet velocity using the lifetime argument (Spangler formulas) and the energy budget arguments of Bicknell; the results are in agreement.

I have used Bicknell model for the jets; here are the best results I have obtained. For the main jet (west) it is possible to obtain a reasonable result while for the counter jet everything is more uncertain.In any case it seems quite certain that for the east jet Rc has to be bigger than for the west jet. I don't know if this is enough to explain the jet asymmetry.

I will be in Boston at the VLBI meeting and after at the VLA for two weeks. It would be nice if could meet and go on with the paper.

Regards

Paola

Velocity of the jets

In both jets $\alpha^{1.4}_{4.9} \sim 0.4$ $\theta < 10''$

$\alpha^{1.4}_{4.9} \sim 0.6$ $10'' < \theta < 20''$

In the west jet $\alpha^{1.4}_{4.9} \sim 0.6$ $20'' < \theta < 40''$

$\alpha^{1.4}_{4.9} \sim 0.8$ $40'' < \theta < 100''$

in the east jet $\alpha^{1.4}_{4.9} \sim 0.8$ $40'' < \theta < 100''$

I get velocities 2-3 times lower than Parker

Using the formulas given by Myers and Spangler 1985 we have computed the jet velocity

In the first 20'' (steepening from 0.4 to 0.6)

$v_j \sim 1200$ km/sec

In the range $20'' < \theta < 100''$

$v_j \sim 1800$ km/sec

From the energy budget arguments of Bicknell we find that

$$v_{jet} \sim 0.25 \, K^{-1} \, f_{L,41} \, P^{-1}_{-10} \left(\frac{\phi}{\text{kpc}}\right)^{-2} \left(1 + \frac{M^2}{6}\right)^{-1}$$

$K = (0.12 - 0.25)$

For $\theta \sim 13''$ $v_{jet} = \begin{cases} 1700 - 3700 & M = 1 \\ 1250 \sim 2600 & M = 2 \\ 800 \sim 1700 & M = 3 \end{cases}$

At this point the Mach number could be ~~three~~ ~ 2

For $\theta \sim 75''$

$$v_j \sim \begin{cases} 580 \\ 1200 \end{cases} \quad \text{for } M = 1 \quad \text{km/sec}$$

This velocity is consistent with the one determined from lifetime arguments

Text Modified: Prandtl incorrect cr Mj 71.8

From Figs. 7, 8 and 9 it is evident that knots are present in the first ~13" from the core (3 knots in 13")

If we assume Bicknell argument, i.e. that shocks arise in a jet which becomes underexpanded as a consequence of a steepening of the external pressure gradient and we use the Prandtl formula:

$$\lambda_k \sim 2.5\,(M^2 - 1)^{1/2}$$

λ_k ~ knot separation in radius units

we find that the Mach number is between 2 - 3 in the first 13" from the core (west jet)

This is consistent with the fact that using Bicknell's model it is possible to fit the brightness - θ diagram only after ~ 15" from the core

The values of the opening angle are consistent with the hypothesis of 0326+39 as a low Mach number jet and thus apply the Bicknell model.

From: 38057::PAOLINA 12-JUN-1989 11:45
To: NRAO::ABRIDLE
Subj: 0326+39

Dear Alan,
here enclosed are some comments on the 0326+39 paper.

1 Page 16 Helical distortions
The expression given by Hardee is quite different from the expression of Ferrari et al. (A.A. 1983,125,?), For the same value of eta, M it differs by ~2 (Ferrari being higher).
Note that in spite of the apparently different analytical expression, the two relationship are smilar, having for instance similar slope with M.
Any idea about this?
Furthermore all the formulae are approximate espressions and valid for M > 5.

2 Page 20 Fit using Bicknell model
All the parameters Beta, eta, Rc , M were varied independently and the best fitting model was determined from the minimun chi-square fit to the surface brightness.
Blong/Bperpend = 1 at the fiducial point theta=5"
It is impossible to obtain a good fit if points with theta < 20"
are included.
In order to obtain a semi-quantitative estimate of the allowable range o
f
each parameter we have determined the values of parameters for which th
e
reduced chi squared is +- 1 removed from its minimum value.
minimim chi square reduced=4.0
1.0 < Rc < 1.4
1.0 < M < 4.0
1.0 < beta < 1.2
0.002 < eta < 0.02

3 Table 2 0.6 GHz
Observing date Jan. 1983 only
Int. spacing 72 + 72 x n

4 Table 3 0.6 Ghz
Int. spacing 147/147/5437
147/147/3234

Zero offset ~ 0.1 mJy

5 Table 8
There is a mixture of units (J and gauss)

6 Fig. 21
This figure was sketched by hand by Roberto. Maybe it is better

to have the drawing done by NRAO graphics.

Fig. 22

At the moment we have some problems with graphics library and it is impossible to have a good version of the spline fit of the opening angle. Could you take care of it using the old figure I sent you ?

7 Figure caption Fig 22

Results of fitting a Bicknell model with
beta = 1.0
Rc=1.4 ?
W0=9.5
eta=0.004
m=1.0

These values give the best fit corresponding to a reduced chi square of 4.0

I am sending all other figures by air mail.

Paola

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From: ESTCS0::PSI%SPAN.DWINGELO::RZMVX1::SBAUM "stefi baum at dwingeloo" 3-SEP-1989 05:25
To: BRIDLE
Subj: 0326 comments at last!

Well, I finally got to the 0326+39 paper. Hope it isn't too late to give you comments. Sorry to have taken so long, but it has been a super busy summer.

Following are some comments from me (and Chris - I had him read it as well and he should be acknowledged for helpful comments [notice all the extra references to O'Dea!!!!]).

Page 6. reference O'Dea and Owen 1987 for irregular spreading of the jets in NGC1265.

Page. 12. Laing-Garrington effect pointed out, but velocity estimates for this source are 500-1000 km/sec. So, either velocity estimates are too low, or the Laing-Garrington effect (at least in this source) is not due to Doppler Boosting/orientation. Should comment on this.

Paola? In the abstract, we say that there is a RM gradient, but that we can't rule out a Galactic origin for the gradient. Can we use the RM of sources near 0326 in the sky and the work of Simmonetti et al on galactic RM fluctuations to rule this out. There should at least be some discussion of this in the text.

The data in sectin 6.4 seems to suggest that the RM gradients are smaller on the Easter lobe, where the lower polarization and fainter jet is. Is his correct? If yes, we could discuss its relevance to the Laing-Garrington effect.

Entrainment is suggested to increase density contrast. Can we compare the rates we need with the rates found by De Young?

Page 18. O'Dea (1985) also estimates light jets in NATS consistent with Williams 1985.

Page 20. Reasons why Bicknell's model doesn't fit 0326 but does N315
(a) different galactic atmosphere and environment for 0326 than in N315?
(b) particle acceleration in the jets in 0326?
(c) are they the same radio power regime?

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May 16, 1989

Dear 0326+39 co-conspirator,

Here, scandalously overdue, is a draft of the detail paper on our B2 0326+39 WSRT/VLA observations. It got "nearly finished" several times -- just as some large task landed on me to bury it again! I'm sorry it's languished for so long; the fault is entirely mine. I've tried to bring the discussion and references up to date, and I still think it has some interesting things to say.

You may recall that Ed did the initial reductions of the VLA data, then Stefi put it through self-cal and MX to increase the dynamic range and to reduce the effects of the confusing sources. Paola did the WSRT/VLA comparisons, and produced the first draft. I sliced the jet and did the "standard stuff" on collimation and brightness evolution. That's where it sat in the summer of 1985, with some "single-velocity" parameter estimates. Since then, we've talked with Geoff Bicknell about variable-velocity models, and Geoff's modeling program arrived in Bologna. Paola sent me some fits of Geoff's model to the data in the summer of 1987, with her suggestions for the next draft. Because the spectral gradients were used for velocity estimates, I redid the VLA spectral analysis more carefully this winter, keeping better track of the error budget and removing the radio core. While updating the discussion, I've also recast some of the logic. It now tries to make separate estimates for the velocity and Mach number at a few places down the jet so we can test the implied density against the polarimetry for consistency. I've also kept the dependencies on the Hubble parameter and Geoff's "kappa" factor visible until the bitter end. The numbers given here are similar to Paola's from 1987; the main delay since then has been mine in getting organized enough to put it all together again.

I'll have NRAO graphics start work on the drawings as soon as possible, so they should be finished by the time the text is. We've not chosen a journal yet, so please name your preference, as well as sending me your comments on the text. I've tried to keep the spelling European-style. I think there are too many Figures, where could we economize ?

I promise this will stay at the top of my queue until it's on its way!

Best wishes,

#13 28-APR-1989 11:14:34 MAIL

From: 38057::PAOLINA

To: 6654::ABRIDLE

Subj:

Dear Alan here enclosed are the calculations I made for the jet velocity using Geoff foumula

AHB

$13'' \rightarrow 4.40$ kpc

2.92×10^{-12} J/m^3 $\equiv 2.9\times10^{-11}$ erg/cm^3

K = 0.25

theta = 13" distance from the core

phi = 3.5 " jet diameter corresponding at 1.2kpc ✓ H≈100

u min ~ 3 *E-11 erg/cm3 energy density

P min ~ 1 * E-11

L tot = 3.3 * E40 erg/sec computed from a a flux density of 540 mJy for the lobe

theta = 75"

phi = 12.86" 4.5kpc

umin ~ 2.4*e-12 erg/cm3

Press RETURN for more...

MAIL>

#13 28-APR-1989 11:14:34 MAIL

Best wishes,

Paola

MAIL>

Paola

Here is the current draft of "0326" with all the Figures + Tables that I have. Most parts still very much as before.

Still needed — discussion of models for the lobe field, would be good to compare with Laing's.

— discussion of jet velocities. Here I think we must now emphasize variable-velocity models such as Geoff's. Should we try to fit, or get Geoff to fit, a model?

Difficult points — the S symmetry. Figure 20 suggests to me that there is no smooth wiggle in the East jet like that in the West jet for Θ>60". Hence my statements throughout about jets not having S symmetry.

— density estimates. I don't think the upper limits are secure, because of the unknown scales of field reversals (e.g. Laing's arguments in the Green Bank Workshop). So I'm not convinced that we can estimate sound or Alfvén speeds. This makes it difficult to get velocities by several of the rough arguments — might be better to approach via Geoff's analysis?

— VLA/WSRT position angles. Seem more different for lobes than for jet. Could this be real?

— wiggles and velocity → how to cope with variable-velocity jet? Variable ρ_j/ρ_{ext} also? Not sure how to use either the Blandford/Icke or Hardee analysis if M_j and ρ_j/ρ_{ext} vary along jet.

I will put equipartition-normalised scales on Figs. 17/18 (Figs 15–18 replace the <u>old</u> Table 8a).

I'll also put together Fig 11 and Table 7 properly v.soon.

I'm still uncertain how much (more) to say about lobe polarimetry. Would you like to draft what you'd like it to say?

From: ASTB01::PAOLINA   11-JUN-1987 07:56
To: 6654::CVAX::ABRIDLE
Subj: 0326+39

Dear Alan,
I'am sorry, but at the VLA I have been quite busy and only now I have the time to answer you.
It is not really clear to me what you think of the fits obtained with Bicknell's model. Assuming that you agree with what has been obtained then the main points are:
WEST JET
The spline fit of the phi-theta data is obtained with knots placed at theta=5,9,30 arcsec. The spline fit can be considered satisfactory up to theta~120". All models should be valid only up to this point.
The assumptions made in choosing the model parameters are:
eta   ratio of jet to external density   < 1

M   Mach number < 2

Since we don't have any information (X-ray or optical) about the galaxy, the fits were done starting with a beta~1 atmosphere in a King model galaxy and varying beta and Rc until a satisfactory fit was obtained.
As you can see from the plots I sent you it is impossible to obtain a good fit for theta<20" while the fit is satisfactory (?) for theta>20". This region corresponds to the first expansion regime of the jet and it is the region where blobs are present. A possible explanation is that in this region Bicknell'as model is not applicable (for example M>2 as can be deduced from the ratio diameter-separation of the blobs).
If you compare the values of d phi/ d theta of 0326+39 with those of NGC 315 you can see that are very similar; what it is very different is the behavior of the brightness that in 0326+39, in the first 20" stays almost constant, while in NGC 315 is decreasing.
Equivalent fits are obtained with sligtly different parameters i.e.:

eta	beta	Wo	Rc	M
0.001	1.1	9,5	2.3	1 - 2
0.01	1.1	9.5	2.0	1.2 - 2

The behavior of the mass flux Fm, which for a physically realistic model should be not decreasing, it is more accurte if M~1.
Also the adiabatic approximation
D ~ .... << 1
works better for an initial value of M=1.
Disregarding the region theta<20" the dynamics of the jet could be explained in terms of BIcknell's model, with the collimation region corresponding to a phase of laminar flow and the subsequent expansion corresponding to a turbulent jer again. In the region of collimation

the percentage of polarization should reach a maximum: what can we say

From: VAX3::PPARMA 20-MAY-1987 23:07
To: CVAX::ABRIDLE
Subj: 0326+39

I am at the VLA until friday may 29. I hope you have received the comments I sent; I have been workon on with Geoff program and there is no way to fit the brightness-phi relation enterely as it has been done for NGC315. Although the two jets have similar regimes with similar dphi/dtheta in 0326+39 the brightness does not decreas enoughbut it remains almost constant.Since where this happens is the initial part of the west jet where blobs are present itis not unreasonable to think that the conditions are different from that required byGeoff model(for example Mach number higher than 2).

Paola

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From: CVAX::ABRIDLE 22-MAY-1987 13:54
To: VAX3::PPARMA,ABRIDLE
Subj: RE: 0326+39

Just got your message (I have been away since May 19). The "particle age" and the "jet flow age" only have to be the same if there is no reacceleration, so I am never sure how much weight to put on the spectral connection when estimating velocities. We also have reverse gradients in this jet which indicate directly that the "particle ages" can't be the same as the "jet flow ages" at the extremity of the wiggle in the west jet.

Perhaps if you could send me some text with what you think should be said about fitting (or not fitting) the Bicknell model to the I-phi data, I could Vaxmail you another iteration with everything included. I will be away again later this afternoon until Tuesday morning, but will then be here for the rest of your time at the VLA.

Best wishes, Alan

==

about it? From the plot you sent me it looks as if the opposite is happening.

EAST JET
The fits obtained are not really very good. The only information they give is that the parameters of the model {Rc for example) have to be different from the west jet.

Raffaella Morganti, a Ph. D. student, has modified Bicknell's programs in a way that for every value of brightness it takes into account the associate error; maybe it would help if you could send me a file with the errors for the intensity to obtain a better fit.
Maybe it is worth trying.
Let me know if you need other informations.

Regards

Paola

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Bologna November 11, 1885

Dear Alan,

here are the comments on the 0326+39 paper.
I am sorry I could not call you back in time when I was at the VLA, but I got your message too late since I was sleeping most of the day and working during the night.
Roberto and I have read the draft you sent me and we have made some comments. Most of them are on the rotation measure; concerning the discussion we have only listed a number of points we think should be discussed. The actual writing still has to be done, if possible by one person only (for uniformity). Let us know if you are willing (and have time) to do it. If not, please tell us so that we may start with it.
In our opinion you should be the first author.
I hope to hear from you soon,

greetings

Paola

P.S. Could you send us at least one copy of the new AIPS cookbook?

National Radio Astronomy Observatory

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Dr. A.H.BRIDLE
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April 4, 1985

Dr. Paola Parma
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Dear Paola,

Here are plots of various of the jet properties in B2 0326+396, as functions of angle from the core and of deconvolved jet FWHM. I will now return to putting the text together with some of these as Figures, but you may want to think about some of the phenomena shown here, so as not to be prejudiced at all by what I write down.

The Faraday rotation gradient seen with the VLA appears to be of the same sign as that in the center of the source from your WSRT data, but offset by a few rad.m^{-2}. I am not sure what to make of this at present. There is no significant depolarization in the jet between 20cm and 6cm. The spectral index distribution seems unusually noisy, and I am not yet sure how much of the fluctuations along the jet to believe. It is very clear however that the knot about 100″ from the core to the west has a flatter spectrum between 20cm and 6cm than either the jet upstream of it, or the lobes downstream of it. This knot also lies near the peak of the northward lateral oscillation of the west jet. I think it may be an example of an internal shock structure resulting from the lateral displacement of the jet, producing local particle reacceleration.

The intensity-width and B_{eq}-width plots are interesting, in that there is a clear subdivision into "subadiabatic" and "adiabatic" regimes that correlates well with changes in the lateral expansion rate.

I mailed today to yourself, to Hans, to Gavril Grueff and to Roberto Fanti, copies of the *Proceedings* of the workshop on energy transport held at Green Bank last Fall. These just came from the printer yesterday. Owing to their weight, they are being sent at book rate, but should be in your hands before long. There is a further copy being sent to your Library. I hope you will find these *Proceedings* interesting.

With best wishes,

Alan

Alan

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March 25, 1985

Dr. Paola Parma
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Dear Paola,

As I started on the analysis of the jet deflection data for B2 0326+396, I realised that the width data I had previously sent you had not been corrected for the jet "wiggle". To be precise, all of the cuts from which I had derived the peak intensities and FWHMs were in p.a. 0°, whereas the jet does in fact "wiggle" significantly. The corrections for the false broadening produced by the "wiggle" are $< 2\%$ for all of the 0.″6 and 2.″0 resolution VLA data, but I took slices in the outer jet at 4.″0 resolution where this correction is quite significant, in the range 10% − −20%. (I am quoting only those jet widths where the uncertainty in the Gaussian fit to the transverse jet profile was $< 10\%$ of the fitted FWHM).

Enclosed are the revised values. The columns are THETA (Θ, angle along the jet from the core, in arcsec); IOBS, the peak intensity of the Gaussian fit to the cut in p.a. 0° at that Θ; PHIOB, the observed FWHM of the Gaussian fit to the cut; IJET′ and PHIJ′, the deconvolved peak jet intensity and FWHM, in mJy and arcsec respectively; LOGINM, $\log_{10}(\mathrm{IJET}/\mathrm{BEAM}^2)$ where BEAM is the FWHM of the CLEAN beam used to restore the map; LOGPHI, $\log_{10}$(PHIJ′); SL#, the number of the transverse cut (slice) across the jet in my internal accounting system; LOGBNM, a normalised measure of $\log_{10} B_{eq}$, the equipartition magnetic field strength, computed from 2*(LOGINM-LOGPHI)/7; LOGUNM, a normalised measure of the minimum magnetic energy density, 2*LOGBNM; DELTA, the position of the peak of the transverse profile along each cut, in arcsec. Due to the way I specified the slice parameters in AIPS, the DELTA values have arbitrary origins; to convert them to absolute deviations from a line at p.a. 90° through the peak of the core source, add 1.″74 to the values at 2.″0 resolution and subtract 0.″53 from the values at 4.″0 resolution.

I am now preparing plots of various parameters of interest to the jet physics. In particular, LOGINM *vs* LOGPHI, and LOGBNM *vs* LOGPHI (which give the intensity and field strength evolution for comparison with "adiabats") and PHIJ′, LOGUNM and DELTA *vs* THETA, which give the collimation, normalised pressure and transverse oscillations of the jet against distance from the core. I will send copies of these as soon as possible. The jet obviously has regions of variable expansion, and both adiabatic and sub-adiabatic segments.

I am also plotting the spectral index, depolarization and RM parameters along the ridge line of the jet at 4.″0 resolution from the VLA data, for comparison with the WSRT data in your draft of the paper. I will send these as soon as I have them available, I hope within a few days (we have a new plotting package that I have to tame before I get these done, but the results should be suitable for direct photography for the paper).

As ever, my regrets that this is not going faster, but at least it *is* going now !

With best wishes,

Alan

Alan

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7 March 1985

Dear Paola,

I am still working on the revision of the text for the paper on B2 0326+396 – I did not have it in a state suitable for you to review by the time I left for the VLA last month. But, to show some progress, here is the collimation ($\Phi(\Theta)$) and intensity-radius ($I_\nu(\Phi)$) data from Gaussian fits to the slices across the VLA 6cm maps. Open circles are from the 0."6 resolution data; filled circles from the 2" data; circles with crosses from the 4" data.

IOBS = measured central intensity on slice in mJy
IJET = ——————————— corrected for Gaussian deconvolution

$$\text{LOGINRM} = \log_{10}\left(\frac{\text{IJET}}{\text{FWHM}^2}\right)$$

Note the excellent agreement between the data at different resolutions where they overlap. Also the very clear "collimation shoulder in both jets ~ 20" from the core, and the overlap of the jet and counterjet $I(\Phi)$ plots after the counterjet has "turned on."

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21st January 1985

Dear Paola,

You may not believe this, but I am now working on the 0326 paper! I have some changes to suggest in the order of the topics as we add the VLA data, so I am retyping it on the Vax here and will send you a completely retyped version.

The main thing I feel about the data presentation is that we should give up the historical order of the maps, and present them in the order which the reader may find most useful. I therefore suggest the following section plan:

1. Introduction
2. Observations and Reductions
   - 2.1 WSRT
   - 2.2 VLA
3. Full-resolution maps
   - 3.1 WSRT 610 MHz
   - 3.2 WSRT 1.4 GHz
   - 3.3 VLA 1.5 GHz
   - 3.4 VLA 4.9 GHz (2" and 0".6)

   (WSRT 5 GHz was already in IAU 97, so we need not repeat it?)
4. Multifrequency comparisons
   - 4.1 Lobes
   - 4.2 Jets
   - 4.3 The unresolved core
5. Physical discussion.

In this scheme I would introduce the convolved maps only if and where the side-by-side comparison of two maps at the same resolution seems particularly useful. Otherwise, let the plots of the derived parameters (α, depolarization, RM) speak for themselves.

I will follow this with my outline for new text of Sections 1-4 as soon as possible. I won't comment on Section 5 yet as my thoughts are too rudimentary.

I will try to have a full draft on its way to you by the middle of February, when I go to the VLA for 2 weeks.

With best wishes,

Alan Bridle

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Bologna May 27 1982

Dear Alan,
we have already received and corrected the proofs of the paper about B2 1321+31 and sent them back. In few months it should be published in Astron. Astrophys. Only 0326+39 is left now. I suppose you have been busy with the big observing program of the B3 sources, but it would be nice to have it finished for the end of the year. We are thinking to ask new observing time at WSRT, 50 cm, double baseline, for both, 0326+39 and 1321+31, in order to better study the polarization distribution and we would like to be able to present at the P.C. some written results. Let us know if you want to be in the proposal.
If you are too busy, you could send to us the VLA data and a summary of the points you want to discuss and we can try to do the rest.
After the summer I have to talk in a workshop about jets, in particular magnetic fields in jets; is there anything new? (after Albuquerque 81)
Hoping to have an answer,
best wishes

Paola Parma

Comments to the draft.

i) (Abstract/3.3/4.2a) Simmetry of the jet.

We think that also the east jet has a wiggle, more or less at the same position from the core as the west one, and with same shape. This is better visible in the WSRT 6 cm map, although we see a hint of it also in the VLA maps, where the jet has a lower contrast with the lobe. It is certainly difficult to measure reliable the wiggle (and jet opening angle), but we feel that it is there.

Abstract → "much more pronounced"

But - Fig.20 (Δ vs. θ) says "no" out to 90° - not a continuous wiggle.

2) (4.2d) Rotation measure along the jet.

As you already noted (letter of april 4), there is an off-set, between the rotation measures we deduce from the VLA and the WSRT, of ~ 7 rad/sq.m.). We have re-examined the WSRT data and found no explanation. We suggest to leave the text as it is now, on this point.

3) (4.2c) Degree of polarization in the jet at 50 cm.

The WSRt data show significant depolarization between 1.4 and 0.6* GHz. In terms of the slab model this would allow to estimate the internal thermal plasma density; it requires an internal rotation measure of ~ 10 rad/sq.m. However, in view of the Faraday gradient found both in the VLA and WSRT data, it is likely that the depolarization is due to a side-side effect. So

* $D^{0.6}_{1.4} = P_{0.6}/P_{1.4} \simeq 0.15 - .20$

only upper limit to internal R.M. (< 10 rad/sq.m.) and to intern thermal density (< 10E-3 cm-3) can be estimated.

4) (4.3c) Lobe depolarization.

There is no relation between rotation angle and depolarization between 21 and 50 cm.

On the contrary there is a clear relation between fractional polarization at 21 cm and depolarization between 21 and 50, as mentioned in the text.

5) (4.3d/5.2a) Rotation measure of the lobes.

The WSRT maps give a good measure of the rotation angle $\theta 50 - \theta 21$ on the west lobe (with the usual ambiguity of $n\pi$). This angle is not constant, but varies quite regularly across the lobe by up to ± 40 deg. This regularity suggests us a constant value of n over the lobe. We tried to estimate n by using the p.a. of the polarization at 5 GHz in the only part of the lobe where it is significant at ~ 4-5 level (namely in the south ridge at R.A. ~ 03h25m53s, Dec. ~ 39 36' 40"). This indicated n = 1 and an R.M. in the lobe ~ 20 - 30 rad/sq.m. Is the p.a. we measure in the WSRT 5 GHz map consistent with that from the VLA? It seems to us that the VLA data indicate a p.a. different from the WSRT one by 20 - 30 deg. Using the VLA p.a., one would rather get n = 2. We think that at this stage the R.M. and therefore the magnetic field orientation is uncertain by 20 - 30 deg. The magnetic field orientation is still likely to be circular around the lobes, but it seems impossible to work out the details.

[We cannot provide a computer made H map, because we do not have the WSRT 21 cm map pn tape, but only a numerical printout].

Note that, for n = 2, the rotation to be applied at 21 cm. E vector map would be ~ 90 deg. (±10°), so that the E vectors orientation at 21 cm. would also give the magnetic field map.

60 (6.a/b) Discussion.

Only a list of points for discussion.

a) Equipartition energy density :

ueq ~ 10E-11 - 10E-12 erg/cm3 from 7 to 30 Kpc (20" - 80")

b) Thermal plasma density :

nth < 10E-3 cm-3 ← why ?

c) Internal sound speed :

Vs > 700 Km/s ← needs ρ.

d) Initial opening angle :

dθ/dz ~ 0.2 ---->

--> Initial Mach number : Mi ≤ 10

--> Initial velocity : Vji ≲ 10000 Km/s

$v_s > 700$, $M_j < 10$ → v_j (??)

e) Brightness plateau : according to Bicknell model velocity decrease $V_{ji}/V_{jf} \sim 4 - 5$

Mach number $M_f \sim 1 - 2$ -----> $V_{jf} \sim 1000 - 2000$ KM/s

$V_{ji} \sim 4000 - 10000$ Km/s

(also lack of hot spot ----> $M_f \sim 1$?)

Have fitted a Bicknell model?

f) external atmosphere, in the slowing down regime

$p(z) \propto z\exp-1$

g) Energetics

energy flow at 20" (~ 7 Kpc): $F(u_{eq}) \sim 10E32\ V_{ji}$ erg/s

(we do not know about K.E.).

Source radioluminosity : R.L. ~ 3 x 10E40 erg/s

Assuming : $\varepsilon\ F(U_{eq}) \sim$ R.L.

and taking $1/\varepsilon \sim 10 - 20$ (adiabatic expansions only), then

$V_{ji} \sim 3 - 6 \times 10E8$ Km/s.

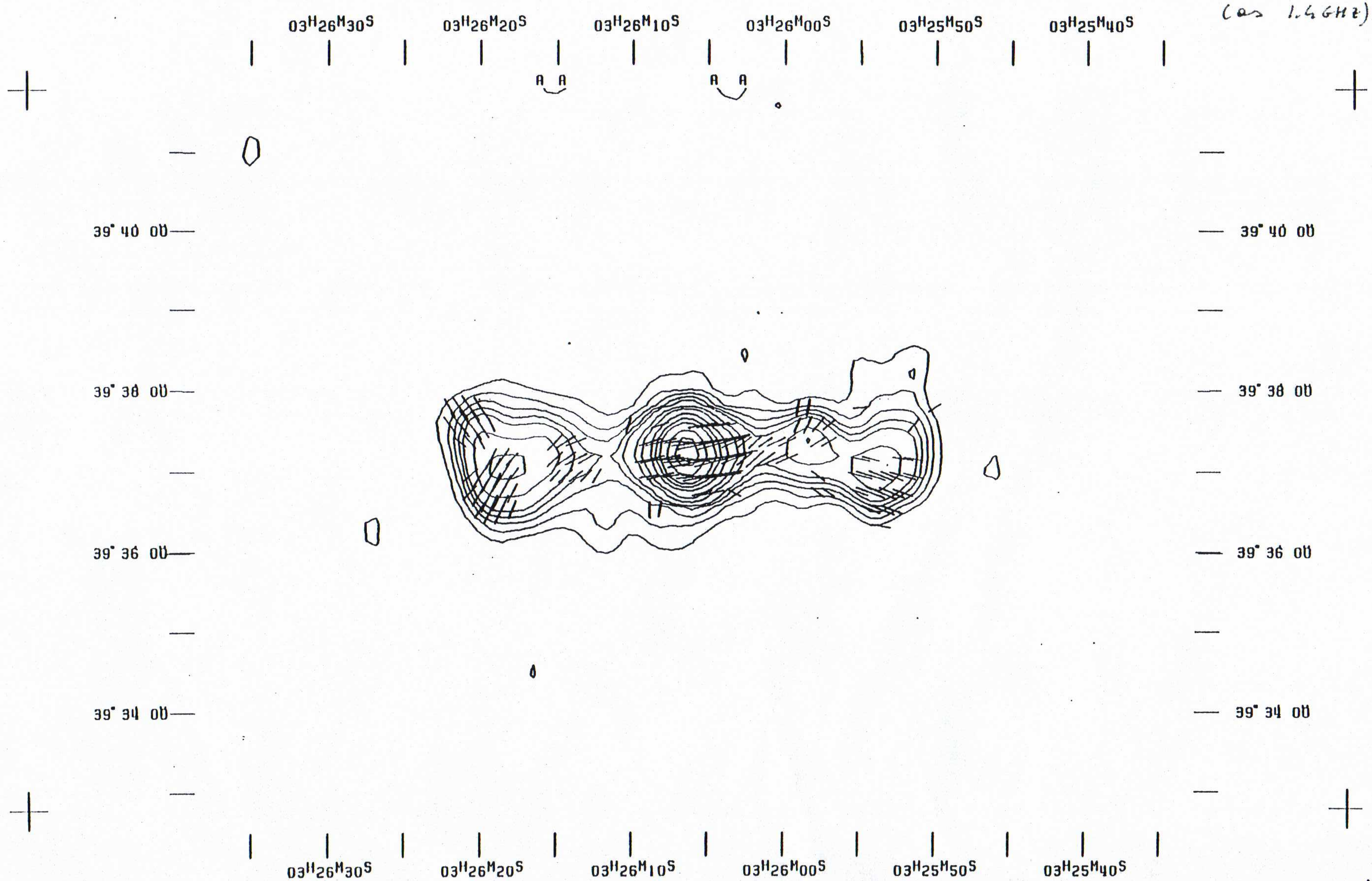
h) Wiggles.

If due to gravitational interaction with the companion, than wiggle wavelength ~ orbiting period x jet velocity -----> $V_{jf} \sim$ 700 KM/s(not to dissimilar from previous estimate). In this case the velocity, for z < 40", had to be much higher in order to wash out in that range the orbiting effect (so in agreement with above).

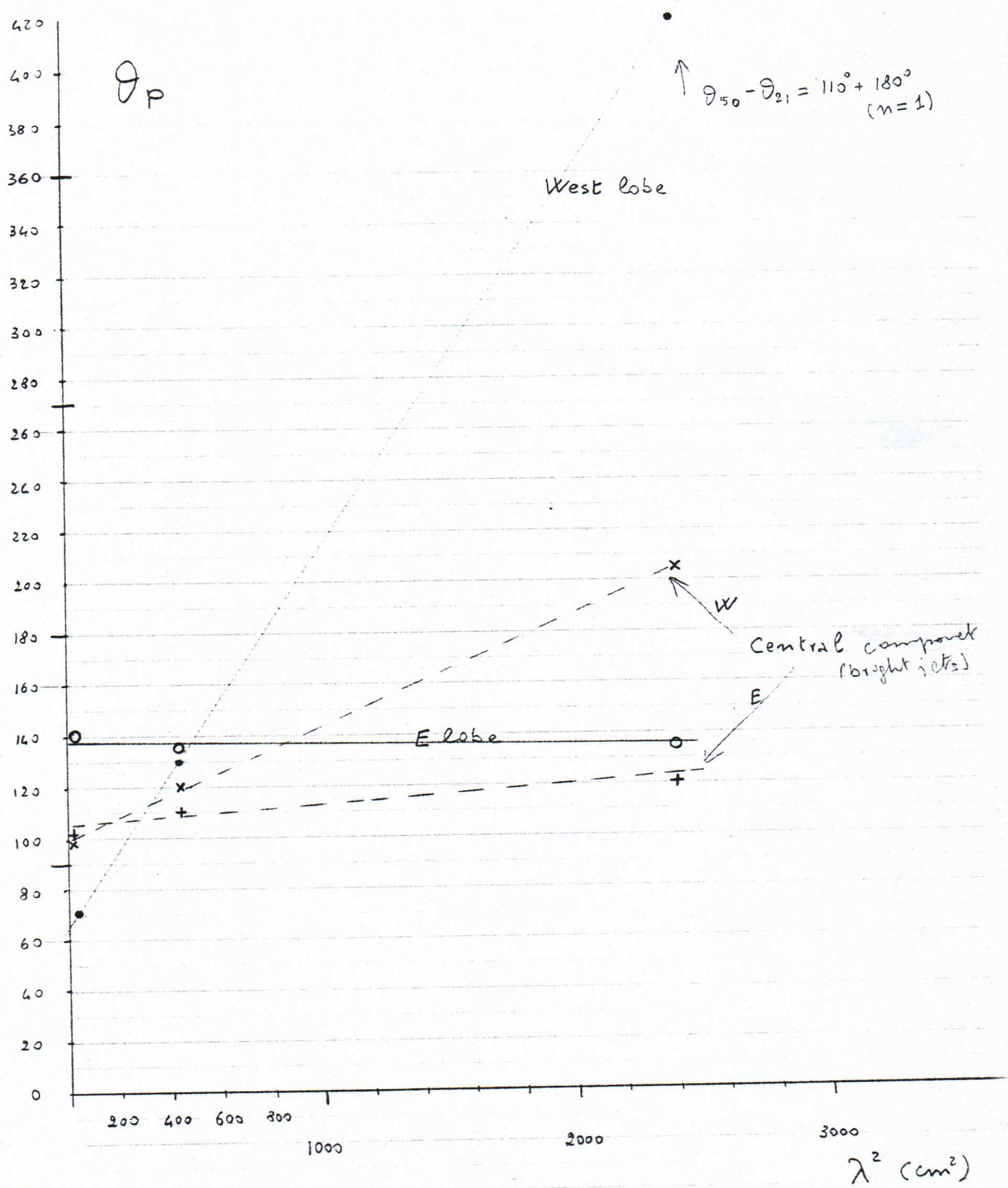
If the wiggle were due on the contrary to K-H instability, a high Mach number would be required (~6) in the range were the wiggle is prominent.

more likely if not symmetric?

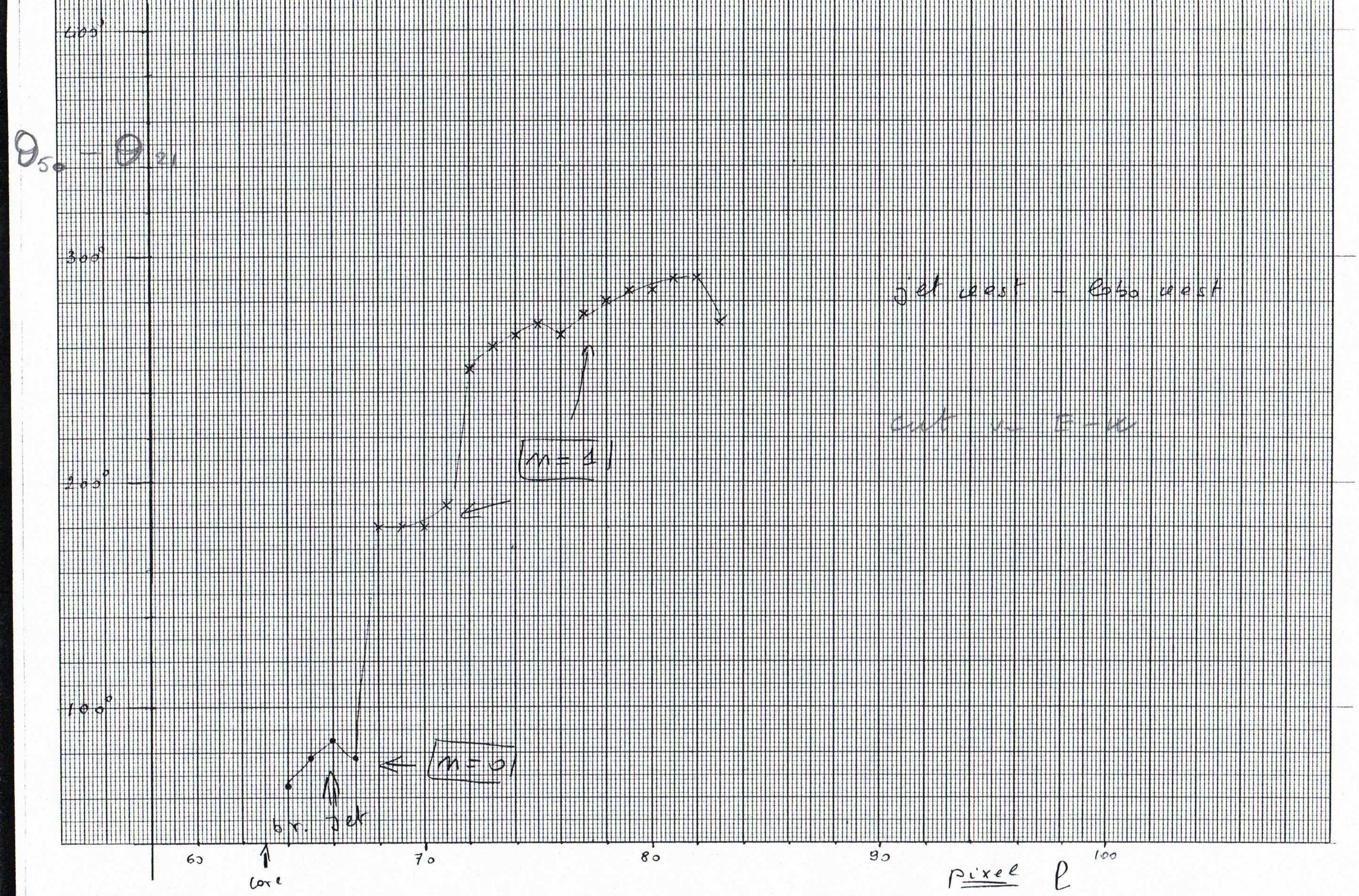
5 GHz WSRT map
26"x41" beam
(as 1.4 GHz)



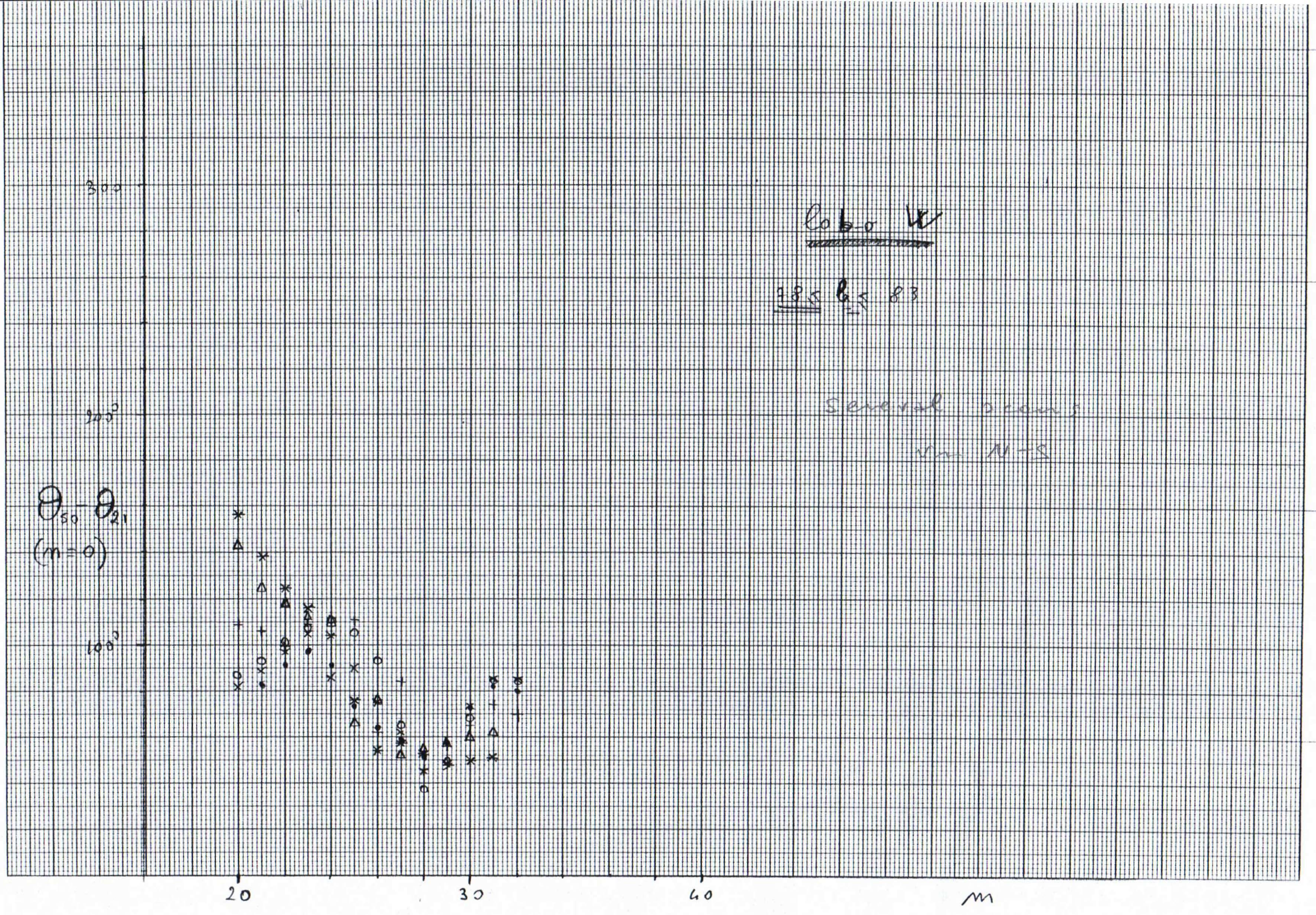

Lobo W
$D^{0.6}_{1.4}$
1.0
.5
.5
P(1.4)
$P_{1.4} > 0.2$
$0.1 < P_{1.4} < 0.2$
$P_{1.4} \leq 0.1$



θp
θ50 − θ21 = 110° + 180°
(n = 1)
West lobe
E lobe
W
E
Central component
(bright jets)
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
200
400
600
800
1000
2000
3000
λ² (cm²)



$\theta_{50} - \theta_{21}$
400°
300°
200°
100°
60
70
80
90
100
core
br. jet
m = 0
m = 1
jet west – lobo west
cut in E–W
pixel ℓ


300
200
100
θ50 - θ21
(n=0)
Several
20
30
40
m