From: Rick Perley <rperley@aoc.nrao.edu>
To: abridle@polaris.cv.nrao.edu
Subject: Re: Scorch marks
Date: Thu, 1 Oct 92 14:37:56 MDT

Well, this comes from ideas we were tossing around last June. I can't say I understand those lines either, but here goes: (Incidentally, there's no problem with dropping these, I thought it would be fun to speculate wildly, for a bit).

We had discussed the interesting possibility that the 'prime mover' in this jet might be invisible, and that because of the alignment and small size of the jet tips, the prime mover might be very thin and very stiff. Now, if the TRUE outflowing material is unseen, until it gets to the terminal shock (jet tips), what then consititutes the 'jets' as we see them? The simple answer would be that these are 'backflow', or 'cocoons' , marking what is left behind as the (reborn, invisible) jet pushes on through the jet lobe. (In my mind, the 'jet' here is analogous to the older, pre-existing lobes). However, two real big problems (objections) are raised here: (1) How can the length and separation asymmetries of the jet/counterjet be explained. The Doppler explanation is very clean and attractive, and it would be nice to preserve it in this speculative model. The only way I can think of this is that the motion of the tip, evacuating the (lobe) material somehow draws the 'backwash' (visible jet) along, at relativistic speeds, so that the 'backwash' is a backwash w.r.t. the (invisible) jet tip, but is still moving forwards (quickly) w.r.t. the viewer. (2) If the 'jets' asymmetry can be explained by this, what about the jet tips? They must be moving faster than the jets, yet they are of about equal brightness. The only thing I can handwave here is that complicated flow patterns in these tips, combined with beaming, might somehow arrange the equal brightness. (Yeah, I know -- WEAK, REAL WEAK!)

As for the 'scorch' marks (this is Dreher terminology), I image the rigid invisible jet to be rotating, essentially carving out a narrow cylinder as it moves forward (and filling up the tube, forming the visible jet). The point of contact between rigid jet and lobe fills with the most energetic particles, and thus forms a helical trail -- a scorch mark.

Hey, we gotta get imaginative here! The old models don't work! (But I'm not claiming mine is any better -- perhaps it will stimulate a decent argument)

Hope this helps.

Rick

From: dclarke@chandra.harvard.edu (David Clarke)
To: rperley@aoc.nrao.edu
Cc: abridle@aoc.nrao.edu, dclarke@chandra.harvard.edu
Subject: Re: 3C219, Ver 2.0
Date: Thu, 1 Oct 92 16:42:57 EDT

Looks good. Fine about the units. Hubble constant a good idea, but not a biggie. As for the spectral index, I found that to first order, one's general expectation of what missing spacings will do to the spectral image is OK, but when you look at it closely, the actual effects are often surprising. If you are not working with databases with *identical* u-v coverages, you just don't know what to trust from comparison images such as the spectral index. As you know, I went to the trouble of generating "false" images of the 1".4 databases which I then "observed" with my various u-v coverages. I found the 18 and 22 cm databases to be virtually identical (spectral index of my false images was zero everywhere) but between 6 and 18 cm, I found important differences even in places other than the brightest features. Your statement that the same spectral indices are found when you compare 6 and 3.5 cm images is encouraging, but still - since you don't have a 6 cm database with the same uv coverage, you can't *know* that there aren't inherant problems.

That said, if you guys are satisfied with the spectral index images as is, then that is good enough for me. At some point, though, I might like to generate some false images just to be sure. I would be willing to do this, for example, before we publish this stuff "for real".

Other than my address and the references, this looks fine to me. Thanks Rick for spearheading this.

Cheers, David

```
From: abridle (Alan Bridle)
To: rperley, dclarke@cfa.harvard.edu
Subject: SARA draft, Version 3.0?
Date: Thu, 1 Oct 92 20:27:59 -0400
```

I've worked over Rick's draft with a few embellishments and some rewording. Basically, I couldn't quite make sense of the the drill bit and felt the problem with the travel time differential in the born-again model was getting obscured. So this goes in the same direction as Rick's draft everywhere, but with slightly different emphasis and a few extra details.

```
%  Dear SARA participant,
%                            Please find below a LaTeX template file
%   which should be used to produce your review/talk/poster paper.
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%   any further.
%
%   The idea is that the author modifies the text but leaves
%   any LaTeX definitions unchanged.
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%    Note that the maximum number of pages is as follows:
%      Reviews                   6 pages
%      Oral presentations        3 pages
%      Poster presentations      2 pages
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%    before the 15th of October deadline:
%       1) A camera ready hardcopy of the review/talk/poster
%       2) The LaTeX file used to produce the hardcopy.
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%
%    If you have any problems please contact:
%
%    Antonis G. Polatidis  (AP2)
%    Michael A. Garrett    (MAG)
%
%    ----------------------------  CUT HERE  ------------------------------
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%
\documentstyle[12pt]{article}

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%                                                                            %
%    Preamble for producing a uniform format for                             %
%                                                                            %
%    Boolean function compexity :                                            %
%    Selected papers from the LMS Durham symposium.                          %
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%    Please include all lines ending with %LMS in your document.             %
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\pagestyle{headings}                                                    %LMS
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% 1. Smaller section titles                                             %LMS
\def\section{\@startsection {section}{1}{\z@}{-1.5ex plus -.5ex         %LMS
minus -.2ex}{1ex plus .2ex}{\large\bf}}                                 %LMS

% 2. Period after a single section number                               %LMS
\renewcommand{\thesection}{\arabic{section}.}                           %LMS
\renewcommand{\thesubsection}{\thesection\arabic{subsection}.}          %LMS
\renewcommand{\thesubsubsection}{\thesubsection\arabic{subsubsection}.} %LMS
\renewcommand{\theparagraph}{\thesubsubsection\arabic{paragraph}.}      %LMS
\renewcommand{\thesubparagraph}{\theparagraph\arabic{subparagraph}.}    %LMS

% -- but avoid a double period                                          %LMS
\def\@thmcountersep{}                                                   %LMS

% 3. Period rather than colon in figure captions                        %LMS
\long\def\@makecaption#1#2{\vskip 10pt \setbox\@tempboxa\hbox{#1. #2}   %LMS
   \ifdim \wd\@tempboxa >\hsize   % IF longer than one line:            %LMS
       #1. #2\par                 %   THEN set as ordinary paragraph.   %LMS
     \else                        %   ELSE  center.                     %LMS
       \hbox to\hsize{\hfil\box\@tempboxa\hfil}                         %LMS
   \fi}                                                                 %LMS

%4. Put running heads in paper.                                         %LMS
\def\ps@headings{                                                       %LMS
 \def\@oddhead{\footnotesize\rm\hfill\runninghead\hfill}               %LMS
 \def\@evenhead{\@oddhead}                                              %LMS
 \def\@oddfoot{\rm\hfill\thepage\hfill}\def\@evenfoot{\@oddfoot} }      %LMS

%5. Number theorems etc. according to sections.                         %LMS
\newtheorem{Theorem}   {Theorem}   [section]                            %LMS
\newtheorem{Corollary} [Theorem]   {Corollary}                          %LMS
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%6. Define \Proof and \qed.                                            %LMS
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\newcommand{\qed  }{\hfill$\Box$}                                      %LMS

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% Follow this example to produce your own title and running head.
% The running head should not be more then 50 characters long, including
% blanks.
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\title{Fine Structure in the Jets of 3C~219}{}{}

\def\runninghead{Perley, Bridle and Clarke:\quad The Jets of 3C219}

%
\author{
{\em   R.A. Perley, A.H. Bridle, D. A. Clarke
     \thanks{NRAO, P.O. Box O, Socorro, New Mexico, USA 87801}
}
%
}

\date{} % no date wanted.                                             %LMS

\begin{document}

\pagestyle{headings}                                                  %LMS
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\maketitle
%\vspace{-10pt} % include according to taste.

\begin{abstract}

VLA observations at 2 and 3.6 cm of the ``partial'' jet and counterjet
in 3C219 at resolutions of 0.18 to 0.4 arcseconds have revealed fine
structure with important implications for jet models.  Both jets
abruptly end at bright, compact features, dropping from the maximum to
zero intensity in less than 100 pc.  There is no evidence
of bow shocks in advance of either jet.  The jet tips are of similar
size and brightness, and are aligned with the core with a bend angle
of less than 0.2 degrees.  Sinusoidal (and thus possibly helical)
oscillations in the ridge lines of both jets are found, with inverted
symmetry.  The jet edges are remarkably linear, despite internal
variations in structure, and are limb-brightened.  There is
evidence for a previously unknown nuclear jet of length $\sim$ 2 Kpc,
pointed towards the main (SW) jet.  Away from the tip of the SW jet, the
spectral index above 5 GHz is very steep, exceeding 1.0 in most places.

\end{abstract}

\section{Introduction}

3C219 is a moderately luminous ($P_{1.4}= 3 \times 10^{26}$ W
Hz$^{-1}$) FRII radio galaxy with a bright jet that extends for 18
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arcsec to the SW from the nucleus, and a fainter counter-jet that extends to about 5 arc sec from the nucleus to the NW. The jet is of particular interest because it disappears abruptly despite the presence of a bright hotspot some 60 arcseconds from the nucleus which presumably signifies a continuation of an active jet somewhere beyond the apparent point of disappearance.

Clarke {\sl et al.} (1992) proposed two models to explain the observed structure of 3C219:

(a) Symmetric, relativistic, restarting jets feeding lobes and hotspots that are remnants of earlier activity, with the brightness asymetry of the jets being due to Doppler favoritism and the length asymmetry being being due to the difference in light travel time to the observer from the approaching jet and receding counterjet. In this model, outward-moving shocks at the leading edges of the jets decelerate them and make the counter-jet tip visible by reducing a previously unfavorable Doppler factor.

(b) A continuous, two sided jet, whose emissivity is enhanced close to the galaxy through lateral compression from X-shocks caused by the adjustment of the supersonic flow to the declining external pressure gradient. The emission is quenched when the jet comes into pressure equilibrium with the atmosphere. In this model, the brightness asymmetry is ascribed to a side-to-side aysmmetry in the pitch angle of the magnetic field (higher pitch angle in the counterjet) and the geometrical asymmetry is random.

Both models can account for some aspects of the large scale structure, but both contain {\sl ad hoc} assumptions. The sensitive high resolution observations reported here were made in attempt to discriminate further between the models.

\section{Observations}
Two eight-hour sessions with the VLA were used to observe 3C219 at 3.6 and 2cm in the {\bf A}-configuration in Sept. 1991. The data were reduced following standard procedures, and both CLEAN and Maximum Entropy algorithms were used to deconvolve images. The final rms noise at 3.6cm was 10μJy per beam. The image shown in Fig. 1 reveals the following new features: (1) The emission drops from the maximum of 12 mJy/sq. arcsec to zero within 100 pc of each jet tip. There is no compact emission anywhere between the jet tips and the hotspots. (2) The tips of the jet and counter-jet are remarkably similar to each other in size and brightness. (3) A line drawn from the jet tip through the nucleus passes through the counter-jet tip within 0.05 arcseconds, so the maximum bend angle is 0.2 degrees. (4) Sinusoidal structures are present in both jets, with inverted symmetry. (5) The edges of the main jet are linear, despite variations in its substructure, and are limb brightened in many places. 96) A 2 Kpc nuclear jet is aligned with the main jet and points toward it. 97) The 3.6 to 2cm spectral index of the SW jet exceeds 1.0 in most places, while the jet tips have spectral indices of 0.5 to 0.7.

\section{Discussion}

The abrupt ends and bright tips of the jet and counterjet pose a strong challenge to the continuous flow/field-compression model, which cannot readily reproduce such rapid quenching of the emissivity. In contrast, the rapid drop in emissivity and the similarity in structure and brightness of the tips of the jet and counter-jet are predicted by the restarting jet model, as is the inverted symmetry of the internal structures. Does this mean the restarting jet model is favored, and the continuous flow/field decompression model is now to be rejected? Not necessarily.

A supersonic restarting jet propagating through the lobes of a radio source must drive ahead of it a bow shock which travels in a radio-emitting plasma and so must significantly enhance the radio emissivity of the lobe medium. No traces of such bow-shock structures are evident in advance of either jet in 3C219, however. Furthermore, the great compactness of the features at the tips of the jets, and their strong alignment across the nucleus, can be explained in a restarting jet model only under the assumptions of constancy in the jet direction and steadiness of the shock structures in time (because this model holds that the tips of jets are being observed at different times in the frame of the parent galaxy). The line linking the jet and counterjet tips and the nucleus is not the symmetry axis of the more diffuse jet emission, however, and there are hook-like features in both the jet and the counterjet behind their bright tips. These new results question whether an assumption of strong symmetry is reasonable.

The small transverse widths of the jet-tip features relative to that of the main jet, and their alignment across the nucleus, may instead suggest that they mark the termination of an inner ({\sl i.e.,} narrow), rigid, jet that remains unseen until the jet tips. The sinusoidal features may then mark a trail of an interaction that resembles a ``hot spot'' on a rotating drill bit advancing into the ambient medium. The spectral steepening away from the tip of the main jet is consistent with such an intepretation, in which most of the main jet emission would be a ``secondary'' feature left behind by the passage of an invisible ``primary'' jet.

It remains to be seen whether the new details of the internal structure of 3C219 revealed by these observations can be accommodated in either of the models previously discussed by Clarke {\sl et al.}. A successful model should now account for the following: (1) the jet/counter-jet length asymmetry, including the apparent scale asymmetries between the hooks near their tips, (2) the strong asymmetry in brightness between all features except the very tips of the jets, (3) the remarkable compactness of the jet tips, (4) their strong alignment across the nucleus, and (5) the apparent lack of stand-off features marking bow shocks beyond the jet tips. While the ''born-again'' relativistic jet model predicts (1) and (2), (3) remains unexplained, the travel-time asymmetries make (4) coincidental unless the jet direction is very stable and (5) conflicts with a prediction of the model. The field-compression model predicts (3) and (5) but (1), (2) and (4) remain as coincidences or unexplained phenomena.

We conclude that neither existing model is fully satisfactory, and more imaginative models may be needed to explain all the symmetries of the new fine structures revealed by these observations.

\vspace{90 mm}

\noindent

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Fig. 1.  The jets of 3C219 at 3.6cm wavelength and 0.18'' resolution.
The features listed in the text are well illustrated by this contour
image.

% \bibliographystyle{plain}
% \begin{thebibliography}{AHU74}

% \bibitem[AHU74]{AHU} Aho A.V., Hopcroft J.E., Ullman J.D.,
% {\it The design and analysis of computer algorithms.\/}
% {\sl Addison-Wesley, 1974.}

% \end{thebibliography}

\end{document}
```

From: Rick Perley <rperley@aoc.nrao.edu>
To: abridle@polaris.cv.nrao.edu
Subject: Re: Light Bulb on
Date: Fri, 2 Oct 92 10:43:02 MDT

Reasonably Happy is a correct summary. It is now much more tightly reasoned, but has lost some of the speculative parts. Can't have it all, I guess.

The next thing to do is to write this up as an Ap.J. article, perhaps a Letter. I can do this while on my little sabbatical.

Rick

From: Rick Perley <rperley@aoc.nrao.edu>
To: abridle
Subject: A small point...
Date: Fri, 2 Oct 92 13:57:37 MDT

Alan, in your reworking, you say that the field decompression model predicts the compactness of the jet tips. How so? This is not at all clear to me.

Rick

P.s. 'Final' version coming...

From: dclarke@chandra.harvard.edu (David Clarke)
To: abridle@polaris.cv.nrao.edu, rperley@aoc.nrao.edu
Cc: dclarke@chandra.harvard.edu
Subject: Re: Oops,
Date: Fri, 2 Oct 92 17:04:53 EDT

Rick and Alan;

It looks great to me. We have converegd in an impressively short time. I think you have capsulated the pros and cons of the two models beautifully and objectively, and yes, quite obviously either or both just ain't the whole picture.

By the way, as a space saving measure, is there a need to give the Clarke et al reference in the text as well as in a bibliography section? Seems to me one could go.

On a separate note, either of you digested Peter Tribble's "mini-review" on jet-sidedness (MNRAS, v256, p281)? He basically reviews all the asymmetries between the jetted and jetless sides of ERS (depol, spix, arm length, brightness ratios) and asserts that they *all* can be explained in terms of Doppler favouritism, and in the conventional sense - the jetted side. Peter makes an observation that on the counter-jet side, he expects the hotspot to be less compact that the HS on the jetted side, and at times, centre-dimmed. Remind you of anybody? like the northern hotspot in 219? The reasoning goes like this. Unlike conventional wisdom which treats the HS as a cohesive entity all travelling at the same speed, in fact there ought to be a velocity gradient such that the very tip of the HS is travelling faster than the periphery. Thus, on the jetted side, the tip is the most Doppler enhanced, thereby making it even more compact in appearance, whereas the tip on the C-Jet side will be Doppler enfeebled, thereby making it appear less compact, even rim brightened.

At any rate, before I start towing the Doppler-line, do either of you have any thoughts on Tribble's paper and its claim that Doppler favouritism explains even *more* that it is traditionally credited with? I am doing a journal club talk here next week, and this is the paper I have chosen to review. Any comments would be highly appreciated.

Cheers, David.

From: abridle (Alan Bridle)
To: Rick Perley <rperley@aoc.nrao.edu>
Subject: Re: A small point...
Date: Fri, 2 Oct 92 17:24:10 -0400

I thought David had predicted that the final shock would be a region that was small relative to the jet radius, i.e. that we might see and X-crossing region that was significantly smaller than the width of the jet. *How* small is for him to say, of course, and we should run this by him.

From: abridle (Alan Bridle)
To: Rick Perley <rperley@aoc.nrao.edu>
Subject: Re: A small point...
Date: Fri, 2 Oct 92 17:35:09 -0400

Haven't got time to read it through before I leave (any moment now).
Will Moday be o.k. for final comments?

Two real quickies:

my address is 520 Edgemont Road, and VA 22903-2475

half the time we say counterjet, the other half counter-jet. I don't mind which, but we should standardize

I'm worried by your comment that the Figure doesn't reproduce well. If you have it as a .PS file, could you E-mail that so we can check it out? (.PS files are pure ASCII so they can be E-mailed just fine)

From: Rick Perley <rperley@aoc.nrao.edu>
To: abridle@polaris.cv.nrao.edu
Subject: Re: A small point...
Date: Fri, 2 Oct 92 16:49:00 MDT

Miswording on my part. It reproduces well, but is simply small. I took the 3.6cm image (which your produced), contoured it with half the number of contours (every other one), and LWPLA'd it with the linewidth set to 1 (rather than the default of 3). It looks good, but is nearly microscopic.

I'll try e-mail it, if I can figure out how.

Rick

From: abridle (Alan Bridle)
To: rperley
Subject: 219 contours
Date: Mon, 5 Oct 92 10:38:54 -0400

Printed them out this morning (thanks) ...

I found the grid lines distracting, especially the 0.5-arcsec grid in Y, which does not seem terribly necessary. (It might make a good point if the angle was rotated to that one of the grid lines actually passed through the two tips and the core, but as it stands, I'd sooner leave the grid off and make the plot less cluttered).

Also, the contours were not as advertised in the Figure caption, but were 80 microJy intervals starting at 40 microJy per beam.

Why did you decide on this "cheating" interval at the lowest contour by the way/ It's a common practice with MERLIN but one I've never liked. Strictly log contours (which they also use occasionally) have always seemed more honest to me, or strictly linear contours for the first few and then quasi-log.

Cheers, A.

From: abridle (Alan Bridle)
To: rperley
Subject: 219 comments
Date: Mon, 5 Oct 92 10:52:59 -0400

I've read the draft through again as promised, and have a few minor points.

1. The reader can't tell from the contour map whether or not there are additional compact structures. So it's a bit misleading to say "the image shown in Fogure 1 shows .... there is no compact emission anywhere between the jet tips and the hotspots. Perhaps we sould put the "there is" statement in parentheses and prefix it, to read:

(Inspection of the wider-field image shows that there is no compact emission ......)

2. The "nuclear jet" evidence looks pretty flimsy with just the one contour in Figure 1. Is this flimsiness an artifact of the contour-steeping? Would log contours be better for showing this?

3. Figure 1 doesn't reveal anything about spectral index. Maybe we should not number the spectral index statement at the end of Section 1, but should say "comparison of images at ?.?" resolution shows that the 3.6 to 2cm spectral index ...." as a separate item?

4. Trivial typo: two periods after second Cklarke et al. ref on p.3

5. general point. Should probably label nucleus and counterjet on the Figure as the general unwashed reader will not be familiar with the layout of 3C219 and will ask which is what (especially given the rotation, which leaves ouur "SW" llooking like a west jet, etc.

That's all folks!

A.

From: Rick Perley <rperley@aoc.nrao.edu>
To: abridle@polaris.cv.nrao.edu
Subject: Re: 219 contours
Date: Mon, 5 Oct 92 09:35:35 MDT

The 0.5 arcsecond grid line in Y is an AIPSism. Unless there is some way to tell AIPS otherwise, you get this ridiculous spacing. I have GRIPEd about this, as it appears the algorithm employed tries to put the same number of grid lines on each axis, regardless of the axis ratio of the image. But I can certainly leave the grid off. I thought it might be useful to assist the reader comprehension of the remarkable alignment.

I wrote the figure caption quickly, obviously got it wrong.

I chose this 'cheating' interval by a simple algorithm -- the lowest contour level must show the noise, but the levels employed had too many lines for such a compressed image. Thus - remove every other line. But if I removed the odd-numbered multiples, the noise contour would go. So the even multiples it was!

I Positively Detest Logarithmic Contours!

I'll try a couple other schemes. But I intend to mail this thing off this morning. This little submission is not worth a lot of agony!

Rick

From: Rick Perley <rperley@aoc.nrao.edu>
To: abridle@polaris.cv.nrao.edu
Subject: Re: 219 comments
Date: Mon, 5 Oct 92 09:52:55 MDT

1) I'll fix this one.
2) I think the reader will have to trust us on this -- most of the nuclear jet is buried under the core, and won't be visible here.
3) I'll reword this, as you suggeset.
4) Will fix.
5) I'll add some words to the Figure Caption to make this clear. There is no room for Figure Anointment, and my printing is not good enough to make it look decent anyway.

Rick

From: dclarke@chandra.harvard.edu (David Clarke)
To: abridle@polaris.cv.nrao.edu, rperley@aoc.nrao.edu
Cc: dclarke@chandra.harvard.edu
Subject: Where have all the bow shocks gone?
Date: Mon, 5 Oct 92 12:55:18 EDT

Gentle-beans;

Now that I am thinking Doppler boosting, a thought just occured to me regarding our lack-of-a-bow-shock-in-219 problem. In the 3-D simulations I have done with passive fields (when the damn things work, that is), I have been struck by how *little* the jet shows up against the background emission. In my case, there is little to distinguish the column brightness of the jet against the column brightness of the cocoon since it is the same stuff (different densities, sure, but that is overwhelmed by path lengths). For example, as I mentioned before, the X-shocks so prevalent in axisymmetry are all but non-existant in 3D. They ain't stable, so it seems. The only remaining difference I can see between the cocoon and jet emission is that one has a chance of being Doppler boosted. So, suppose for the moment that the reason we see the 219 jet *at all* is that it is boosted by a large factor. So the jet's pointing at us. Then why can't the apex of the bow shock be superposed over jet-tip, thus rendering it indistinguishable from the jet? I would only expect the very tip of the bow-shock to glow, since it is only this that is being Doppler-boosted toward us. Away from the apex, not only is the shock strength decreasing, but it is also losing its Doppler enhancement.

Can either of you think of something to contradict this way out? Have we hashed over this point before and I'm just forgetting the discussion? If so, I can't imagine why I would have dismissed it.

If this is legit, then we have only two, I think, smaller problems with the restarting jet scenario.

1. What is keeping the southern hotspot so compact and bright?

2. What is the origin of the high polarisation feature which extends out from the tip of the main jet? Could that be a Doppler effect too somehow? Could it be evidence of the cavity left by previous jet activity?

Despite these two remaining questions, I think dismissing the bow shock problem would give a restarting jet scenario a major shot in the arm. Food for thought.

Cheers, David.

From: abridle (Alan Bridle)
To: rperley, dclarke@cfa.harvard.edu
Subject: Bow shocks
Date: Mon, 5 Oct 92 14:47:46 -0400

David's last message re-raised a point we have discussed before, but in a new and better-foocussed context. I do recall that whhen David and Rick were separately in C'ville we did question whether the bow shocks could be *superposed* on the jet and counterjet emission, getting them confused with the jets and thus unrecognizable. In particular, I recall us discussing whether the "hook" emission, with its sharp gradient to the *West*, might be part of bow shock at a very short stand-off distance from the jet. But David's last message raises two important new points:

(1) such a superposition is particularly likely if the jet is near the line of sight, as required by the born-again model, and
(2) we may need to take account of different Doppler factors at different places around the bow shock, strongly modifying the bow shock visibility around its arc.

I think we may need to tread more softly about whether some of the emission we've detected *is* the bow shock, partly superposed on the jets, until we have a simulation that could tell us what to expect a mildly relativistic bow shock to look like in the appropriate orientation?

David's ongoing concern about the X-shocks vanishing in 3-D numerical runs is also pretty disturbing. By comparison, the born-again model invokes only ingredients that we already suspect are present in strong AGNs -- relativistic jets and variable-power engines, and the shocks that "should" be present in the face of this combination. The other model already has a much more ad hoc ingredient in the field asymmetry, and may be invoking a class of shock that is now more questionable as well? (Let David be our guide on that, but this seems to be the trend of his recent comments?)

If the bow-shock problem can be confused by superposition and variable boosting factors round the rim as Daid suggests, then the hot spot issue may be the only clear one facing us. (I think the B-perp down the projected jet axis is a byproduct of the models with toroidal field dominant, whether or not there is an extension to the jet).

This brings me back to the old point about superposing the two L-band images. Some people who have looked at the composite image ask about a pair of filaments coming back from the hot spot on this image, and how sure we can be that they are not tracing a wider, edge-brightened jet in the outer part of the SW lobe. I'd really like you guys to tell me what you think about that, as several "independent observers" of our image data have now brought this up. This feature might be a sign of ongoing input to the SW hot spot, with a shorter "dead time" in the central engine than we had previously been envisioning?

I feel that the born-again model faces smaller, and less certain, obstacles than the field-compression model in the light of everything we have been discussing. But I'll admit to a certain fondness for it so there is a possibility of unjustified tilt in its direction on my part. I'd like to hear Rick's views on this before we finally sign off on the sara text ......

```
From: abridle (Alan Bridle)
To: rperley
Subject: Typos fixed
Date: Mon, 5 Oct 92 14:55:15 -0400


Rick, this fixes the typos only in your last draft:

counter-jet    now everywhere  for   counterjet
..             removed after Clarke et al
``born   for   ''born

%  Dear SARA participant,
%                            Please find below a LaTeX template file
%   which should be used to produce your review/talk/poster paper.
%   We suggest you extract this file and process it before proceeding
%   any further.
%
%   The idea is that the author modifies the text but leaves
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%    Note that the maximum number of pages is as follows:
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%    Authors are reminded that they must provide the following materials
%    before the 15th of October deadline:
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%    Please send your hardcopies to
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%           United Kingdom
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%    sara@star.jb.man.ac.uk
%    sara@uk.ac.man.jb.star     (JANET)
%
%
%    If you have any problems please contact:
%
%    Antonis G. Polatidis  (AP2)
%    Michael A. Garrett    (MAG)
%
%    ----------------------------  CUT HERE  -------------------------------
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%
\documentstyle[12pt]{article}

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%    Preamble for producing a uniform format for                         %
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%    Selected papers from the LMS Durham symposium.                      %
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\setlength{\baselineskip}{    15pt    }                                   %LMS
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\setlength{\parskip     }{7pt plus 2pt}                                   %LMS

\makeatletter                                                             %LMS

% 1. Smaller section titles                                               %LMS
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minus -.2ex}{1ex plus .2ex}{\large\bf}}                                   %LMS

% 2. Period after a single section number                                 %LMS
\renewcommand{\thesection}{\arabic{section}.}                             %LMS
\renewcommand{\thesubsection}{\thesection\arabic{subsection}.}            %LMS
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\renewcommand{\theparagraph}{\thesubsubsection\arabic{paragraph}.}       %LMS
\renewcommand{\thesubparagraph}{\theparagraph\arabic{subparagraph}.}     %LMS

% -- but avoid a double period                                            %LMS
\def\@thmcountersep{}                                                     %LMS

% 3. Period rather than colon in figure captions                          %LMS
\long\def\@makecaption#1#2{\vskip 10pt \setbox\@tempboxa\hbox{#1. #2}   %LMS
   \ifdim \wd\@tempboxa >\hsize   % IF longer than one line:              %LMS
       #1. #2\par                 %   THEN set as ordinary paragraph.     %LMS
     \else                        %   ELSE  center.                       %LMS
       \hbox to\hsize{\hfil\box\@tempboxa\hfil}                           %LMS
   \fi}                                                                   %LMS

%4. Put running heads in paper.                                           %LMS
\def\ps@headings{                                                         %LMS
 \def\@oddhead{\footnotesize\rm\hfill\runninghead\hfill}                 %LMS
 \def\@evenhead{\@oddhead}                                                %LMS
 \def\@oddfoot{\rm\hfill\thepage\hfill}\def\@evenfoot{\@oddfoot} }      %LMS

%5. Number theorems etc. according to sections.                           %LMS
\newtheorem{Theorem}   {Theorem}   [section]                              %LMS
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%6. Define \Proof and \qed.                                               %LMS
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\newcommand{\Proof}{\medskip\noindent{\bf Proof :}\quad\medskip}        %LMS
\newcommand{\qed  }{\hfill$\Box$}                                        %LMS

\makeatother                                                             %LMS

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%
% Follow this example to produce your own title and running head.
% The running head should not be more then 50 characters long, including
% blanks.
%
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\title{Fine Structure in the Jets of 3C~219}{}{}

\def\runninghead{Perley, Bridle and Clarke:\quad The Jets of 3C219}

%
\author{
{\em   R.A. Perley
     \thanks{NRAO, P.O. Box O, Socorro, NM, USA 87801},
    A.H. Bridle
     \thanks{NRAO, Edgemont Road, Charlottesville, VA, USA 22903},
    D.A. Clarke
     \thanks{Center for Astrophysics, 60 Garden St.,Cambridge MA, USA 02138}
}
%
}

\date{} % no date wanted.                                               %LMS

\begin{document}

\pagestyle{headings}                                                    %LMS
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\maketitle
%\vspace{-10pt} % include according to taste.

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VLA observations at 2 and 3.6 cm of the ``partial'' jet and counterjet
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structure with important implications for jet models.  Both jets
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The jet edges are remarkably linear, despite internal variations in
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the main (SW) jet.

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\section{Introduction}
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(a) Symmetric, relativistic, restarting jets, with the brightness asymmetry of the jets being due to Doppler favoritism and the length asymmetry being being due to the difference in light travel time to the observer from the approaching jet and receding counter-jet. In this model, outward-moving shocks at the leading edges of the jets decelerate them and make the counter-jet tip visible by reducing a previously unfavorable Doppler factor.

(b) A continuous, two sided jet, whose emissivity is enhanced close to the galaxy through lateral compression from X-shocks caused by the adjustment of the supersonic flow to the declining external pressure gradient. The emission is quenched when the jet comes into pressure equilibrium with the atmosphere. In this model, the brightness asymmetry is ascribed to a side-to-side aysmmetry in the pitch angle of the magnetic field (higher pitch angle in the counter-jet) and the geometrical asymmetry is random.

Both models can account for some aspects of the large scale structure, but both contain {\sl ad hoc} assumptions. The sensitive high resolution observations reported here were made in an attempt to discriminate further between the models.

Two eight-hour sessions with the VLA were used to observe 3C219 at 3.6 and 2cm in the {\bf A}-configuration in Sept. 1991. The image shown in Fig. 1 reveals the following new features: (1) The emission drops from the maximum of 12 mJy/sq. arcsec to zero within 100 pc of each jet tip. A wider-field image shows there is no compact emission anywhere between the jet tips and the hotspots. (2) The tips of the jet and counter-jet are remarkably similar to each other in size and brightness. (3) A line drawn from the jet tip through the nucleus passes through the counter-jet tip within 0.05 arcseconds, so the maximum bend angle is 0.2 degrees. (4) Sinusoidal structures are present in both jets, with inverted symmetry. (5) The edges of the main jet are linear, despite variations in its substructure, and are limb brightened in many places. In addition, a core-subtracted image reveals a 2 kpc nuclear jet which is aligned with the main jet and which points toward it. (The tip of this inner jet is just visible in Figure 1.) Comparison of 0.4 arcsecond images shows that the 3.6 to 2cm spectral index of the SW jet exceeds 1.0 in most places, while the jet tips have spectral indices of 0.5 to 0.7.

\section{Discussion}

The abrupt ends and bright tips of the jet and counter-jet pose a strong challenge to the continuous flow/field-compression model, which cannot readily reproduce such rapid quenching of the emissivity. In contrast, the rapid drop in emissivity and the similarity in structure and brightness of the tips of the jet and counter-jet are predicted by the restarting jet model, as is the inverted symmetry of the internal structures. Does this mean the restarting jet model is favored, and the continuous flow/field decompression model is now to be rejected? Not necessarily.

A supersonic restarting jet propagating through the lobes of a radio source must drive ahead of it a bow shock which travels in a radio-emitting plasma and so must significantly enhance the radio emissivity of the lobe medium. No traces of such bow-shock structures are evident in advance of either jet in 3C219, however. Furthermore, the great compactness of the features at the tips of the jets, and their strong alignment across the nucleus, can be explained in a restarting jet model only under the assumptions of constancy in the jet direction and steadiness of the shock structures in time. The line linking the jet and counter-jet tips and the nucleus is not the symmetry axis of the more diffuse jet emission, however, and there are hook-like features in both the jet and the counter-jet behind their bright tips. These new results question whether an assumption of strong symmetry is reasonable.

%The small transverse widths of the jet-tip features relative to that
%of the main jet, and their alignment across the nucleus, may instead
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%resembles a ``hot spot'' on a rotating drill bit advancing into the
%ambient medium. The spectral steepening away from the tip of the main
%jet is consistent with such an intepretation, in which most of
%the main jet emission would be a ``secondary'' feature left behind by the
%passage of an invisible ``primary'' jet.

It remains to be seen whether the new details of the internal structure of 3C219 revealed by these observations can be accommodated in either of the models previously discussed by Clarke {\sl et al}. A successful model should now account for the following: (1) the jet/counter-jet length asymmetry, including the apparent scale asymmetries between the hooks near their tips, (2) the strong asymmetry in brightness between all features except the very tips of the jets, (3) the remarkable compactness of the jet tips, (4) their strong alignment across the nucleus, and (5) the apparent lack of stand-off features marking bow shocks beyond the jet tips. While the ``born-again'' relativistic jet model predicts (1) and (2), (3) remains unexplained, the travel-time asymmetries make (4) coincidental unless the jet direction is very stable and (5) conflicts with a prediction of the model. The field-compression model predicts (3) and (5) but (1), (2) and (4) remain as coincidences or unexplained phenomena.

We conclude that neither existing model is fully satisfactory, and more imaginative, and complex, models may be needed to explain all the symmetries of the new fine structures revealed by these observations.

\vspace{40 mm}

\noindent
Fig. 1. The jets of 3C219 at 3.6cm wavelength and 0.18'' resolution. The main, or SW, jet occupies the right half of the figure, the counter-jet is seen in the left side, while the nucleus, with the tip of the nuclear jet protruding on the right side, is in between.

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The jet has been rotated by 50.5 degrees and the contour are at
multiples of -1,1,2,3,4,5,7,9,11,13,15,17,and 19 times 35
$\mu$Jy/beam.  An extra contour at 40.9 mJy/beam is added to show the
FWHP of the synthesized beam.

% \bibliographystyle{plain}
% \begin{thebibliography}{}


% \bibitem{} Clarke, D.A., Bridle, A.H., Burns, J.O.,
%      Perley, R.A., and Norman, M.L.,
% {\it Origin of the Structures and Polarization in the Classical
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%\end{thebibliography}

\end{document}
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To: rperley
Subject: Typos fixed
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%
%    If you have any problems please contact:
%
%    Antonis G. Polatidis  (AP2)
%    Michael A. Garrett    (MAG)
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\documentstyle[12pt]{article}

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%    Preamble for producing a uniform format for                          %
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\makeatletter                                                             %LMS

% 1. Smaller section titles                                               %LMS
\def\section{\@startsection {section}{1}{\z@}{-1.5ex plus -.5ex           %LMS
minus -.2ex}{1ex plus .2ex}{\large\bf}}                                   %LMS

% 2. Period after a single section number                                 %LMS
\renewcommand{\thesection}{\arabic{section}.}                             %LMS
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\renewcommand{\theparagraph}{\thesubsubsection\arabic{paragraph}.}        %LMS
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% -- but avoid a double period                                            %LMS
\def\@thmcountersep{}                                                     %LMS

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     \else                        %   ELSE  center.                       %LMS
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   \fi}                                                                   %LMS

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%5. Number theorems etc. according to sections.                           %LMS
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\newtheorem{Corollary} [Theorem]   {Corollary}                            %LMS
\newtheorem{Lemma}     [Theorem]   {Lemma}                                %LMS

%6. Define \Proof and \qed.                                               %LMS
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\newcommand{\Proof}{\medskip\noindent{\bf Proof :}\quad\medskip}        %LMS
\newcommand{\qed  }{\hfill$\Box$}                                        %LMS

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% blanks.
%
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\title{Fine Structure in the Jets of 3C~219}{}{}

\def\runninghead{Perley, Bridle and Clarke:\quad The Jets of 3C219}

%
\author{
{\em   R.A. Perley
     \thanks{NRAO, P.O. Box O, Socorro, NM, USA 87801},
    A.H. Bridle
     \thanks{NRAO, Edgemont Road, Charlottesville, VA, USA 22903},
    D.A. Clarke
     \thanks{Center for Astrophysics, 60 Garden St.,Cambridge MA, USA 02138}
}
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}

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\begin{document}

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\maketitle
%\vspace{-10pt} % include according to taste.

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%\end{thebibliography}

\end{document}
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```
From: abridle (Alan Bridle)
To: Rick Perley <rperley@aoc.nrao.edu>
Subject: Re: In the Mail
Date: Mon, 5 Oct 92 15:41:00 -0400

Rick -

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%    Antonis G. Polatidis  (AP2)
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%
%    ----------------------------  CUT HERE  -------------------------------
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%
\documentstyle[12pt]{article}

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%                                                                        %
%    Preamble for producing a uniform format for                         %
%                                                                        %
%    Boolean function compexity :                                        %
%    Selected papers from the LMS Durham symposium.                      %
%                                                                        %
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\pagestyle{headings}                                                     %LMS
\flushbottom                                                             %LMS

\setlength{\textheight  }{   217mm    }                                  %LMS
\setlength{\textwidth   }{   152mm    }                                  %LMS
\setlength{\baselineskip}{    15pt    }                                  %LMS
\setlength{\parindent   }{     0pt    }                                  %LMS
\setlength{\parskip     }{7pt plus 2pt}                                  %LMS

\makeatletter                                                            %LMS

% 1. Smaller section titles                                              %LMS
\def\section{\@startsection {section}{1}{\z@}{-1.5ex plus -.5ex          %LMS
minus -.2ex}{1ex plus .2ex}{\large\bf}}                                  %LMS

% 2. Period after a single section number                                %LMS
\renewcommand{\thesection}{\arabic{section}.}                            %LMS
\renewcommand{\thesubsection}{\thesection\arabic{subsection}.}           %LMS
\renewcommand{\thesubsubsection}{\thesubsection\arabic{subsubsection}.}  %LMS
\renewcommand{\theparagraph}{\thesubsubsection\arabic{paragraph}.}       %LMS
\renewcommand{\thesubparagraph}{\theparagraph\arabic{subparagraph}.}     %LMS

% -- but avoid a double period                                           %LMS
\def\@thmcountersep{}                                                    %LMS

% 3. Period rather than colon in figure captions                         %LMS
\long\def\@makecaption#1#2{\vskip 10pt \setbox\@tempboxa\hbox{#1. #2}    %LMS
   \ifdim \wd\@tempboxa >\hsize   % IF longer than one line:             %LMS
       #1. #2\par                 %   THEN set as ordinary paragraph.    %LMS
     \else                        %   ELSE  center.                      %LMS
       \hbox to\hsize{\hfil\box\@tempboxa\hfil}                          %LMS
   \fi}                                                                  %LMS

%4. Put running heads in paper.                                          %LMS
\def\ps@headings{                                                        %LMS
 \def\@oddhead{\footnotesize\rm\hfill\runninghead\hfill}                %LMS
 \def\@evenhead{\@oddhead}                                               %LMS
 \def\@oddfoot{\rm\hfill\thepage\hfill}\def\@evenfoot{\@oddfoot} }       %LMS

%5. Number theorems etc. according to sections.                          %LMS
\newtheorem{Theorem}   {Theorem}   [section]                             %LMS
\newtheorem{Corollary} [Theorem]   {Corollary}                           %LMS
\newtheorem{Lemma}     [Theorem]   {Lemma}                               %LMS
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%6. Define \Proof and \qed.                                             %LMS
\newcommand{\Proof}{\medskip\noindent{\bf Proof :}\quad\medskip}        %LMS
\newcommand{\qed  }{\hfill$\Box$}                                       %LMS

\makeatother                                                            %LMS

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%
% Follow this example to produce your own title and running head.
% The running head should not be more then 50 characters long, including
% blanks.
%
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\title{Fine Structure in the Jets of 3C~219}{}{}

\def\runninghead{Perley, Bridle and Clarke:\quad The Jets of 3C219}

%
\author{
{\em   R.A. Perley
     \thanks{NRAO, P.O. Box O, Socorro, NM, USA 87801},
    A.H. Bridle
     \thanks{NRAO, 520 Edgemont Road, Charlottesville, VA, USA 22903-2475},
    D.A. Clarke
     \thanks{Center for Astrophysics, 60 Garden St.,Cambridge MA, USA 02138}
}
%
}

\date{} % no date wanted.                                              %LMS

\begin{document}

\pagestyle{headings}                                                   %LMS
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\maketitle
%\vspace{-10pt} % include according to taste.

\begin{abstract}

VLA observations at 2 and 3.6 cm of the ``partial'' jet and counterjet
in 3C219 at resolutions of 0.18 to 0.4 arcseconds have revealed fine
structure with important implications for jet models.  Both jets
abruptly end at bright, compact features, dropping from the maximum to
zero intensity in less than 100 pc.  There is no evidence of bow
shocks in advance of either jet.  The jet tips are of similar size and
brightness, and are aligned with the core with a bend angle of less
than 0.2 degrees.  Sinusoidal (and thus possibly helical) oscillations
in the ridge lines of both jets are found, with inverted symmetry.
The jet edges are remarkably linear, despite internal variations in
structure, and are limb-brightened.  There is evidence for a
previously unknown nuclear jet of length $\sim$ 2 kpc, pointed towards
the main (SW) jet.

\end{abstract}

\section{Introduction}
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3C219 is a moderately luminous ($P_{1.4}= 3 \times 10^{26}$ W Hz^{-1}) FRII radio galaxy with a bright jet that extends for 18 arcsec to the SW from the nucleus, and a fainter counter-jet that extends to about 5 arc sec from the nucleus to the NW. The jet is of particular interest because it disappears abruptly despite the presence of a bright hotspot some 60 arcseconds from the nucleus which presumably signifies a continuation of an active jet somewhere beyond the apparent point of disappearance. Clarke {\sl et al.} ({\sl Ap.J.},\,{\bf 385},\,173, 1992) proposed two models to explain the observed structure of 3C219:

(a) Symmetric, relativistic, restarting jets, with the brightness asymmetry of the jets being due to Doppler favoritism and the length asymmetry being being due to the difference in light travel time to the observer from the approaching jet and receding counter-jet. In this model, outward-moving shocks at the leading edges of the jets decelerate them and make the counter-jet tip visible by reducing a previously unfavorable Doppler factor.

(b) A continuous, two sided jet, whose emissivity is enhanced close to the galaxy through lateral compression from X-shocks caused by the adjustment of the supersonic flow to the declining external pressure gradient. The emission is quenched when the jet comes into pressure equilibrium with the atmosphere. In this model, the brightness asymmetry is ascribed to a side-to-side aysmmetry in the pitch angle of the magnetic field (higher pitch angle in the counter-jet) and the geometrical asymmetry is random.

Both models can account for some aspects of the large scale structure, but both contain {\sl ad hoc} assumptions. The sensitive high resolution observations reported here were made in an attempt to discriminate further between the models.

Two eight-hour sessions with the VLA were used to observe 3C219 at 3.6 and 2cm in the {\bf A}-configuration in Sept. 1991. The image shown in Fig. 1 reveals the following new features: (1) The emission drops from the maximum of 12 mJy/sq. arcsec to zero within 100 pc of each jet tip. A wider-field image shows there is no compact emission anywhere between the jet tips and the hotspots. (2) The tips of the jet and counter-jet are remarkably similar to each other in size and brightness. (3) A line drawn from the jet tip through the nucleus passes through the counter-jet tip within 0.05 arcseconds, so the maximum bend angle is 0.2 degrees. (4) Sinusoidal structures are present in both jets, with inverted symmetry. (5) The edges of the main jet are linear, despite variations in its substructure, and are limb brightened in many places. In addition, a core-subtracted image reveals a 2 kpc nuclear jet which is aligned with the main jet and which points toward it. (The tip of this inner jet is just visible in Figure 1.) Comparison of 0.4 arcsecond images shows that the 3.6 to 2cm spectral index of the SW jet exceeds 1.0 in most places, while the jet tips have spectral indices of 0.5 to 0.7.

\section{Discussion}

The abrupt ends and bright tips of the jet and counter-jet pose a strong challenge to the continuous flow/field-compression model, which cannot readily reproduce such rapid quenching of the emissivity. In contrast, the rapid drop in emissivity and the similarity in structure and brightness of the tips of the jet and counter-jet are predicted by the restarting jet model, as is the inverted symmetry of the internal structures. Does this mean the restarting jet model is favored, and the continuous flow/field decompression model is now to be rejected? Not necessarily.

A supersonic restarting jet propagating through the lobes of a radio source must drive ahead of it a bow shock which travels in a radio-emitting plasma and so must significantly enhance the radio emissivity of the lobe medium. No traces of such bow-shock structures are evident in advance of either jet in 3C219, however. Furthermore, the great compactness of the features at the tips of the jets, and their strong alignment across the nucleus, can be explained in a restarting jet model only under the assumptions of constancy in the jet direction and steadiness of the shock structures in time. The line linking the jet and counter-jet tips and the nucleus is not the symmetry axis of the more diffuse jet emission, however, and there are hook-like features in both the jet and the counter-jet behind their bright tips. These new results question whether an assumption of strong symmetry is reasonable.

%The small transverse widths of the jet-tip features relative to that
%of the main jet, and their alignment across the nucleus, may instead
%suggest that they mark the termination of an inner ({\sl i.e.,}
%narrow), rigid, jet that remains unseen until the jet tips. The
%sinusoidal features may then mark a trail of an interaction that
%resembles a ``hot spot'' on a rotating drill bit advancing into the
%ambient medium. The spectral steepening away from the tip of the main
%jet is consistent with such an intepretation, in which most of
%the main jet emission would be a ``secondary'' feature left behind by the
%passage of an invisible ``primary'' jet.

It remains to be seen whether the new details of the internal structure of 3C219 revealed by these observations can be accommodated in either of the models previously discussed by Clarke {\sl et al}. A successful model should now account for the following: (1) the jet/counter-jet length asymmetry, including the apparent scale asymmetries between the hooks near their tips, (2) the strong asymmetry in brightness between all features except the very tips of the jets, (3) the remarkable compactness of the jet tips, (4) their strong alignment across the nucleus, and (5) the apparent lack of stand-off features marking bow shocks beyond the jet tips. While the ``born-again'' relativistic jet model predicts (1) and (2), (3) remains unexplained, the travel-time asymmetries make (4) coincidental unless the jet direction is very stable and (5) conflicts with a prediction of the model. The field-compression model predicts (3) and (5) but (1), (2) and (4) remain as coincidences or unexplained phenomena.

We conclude that neither existing model is fully satisfactory, and more imaginative, and complex, models may be needed to explain all the symmetries of the new fine structures revealed by these observations.

\vspace{40 mm}

\noindent
Fig. 1. The jets of 3C219 at 3.6cm wavelength and 0.18'' resolution. The main, or SW, jet occupies the right half of the figure, the counter-jet is seen in the left side, while the nucleus, with the tip

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of the nuclear jet protruding on the right side, is in between.
The jet has been rotated by 50.5 degrees and the contour are at
multiples of -1,1,2,3,4,5,7,9,11,13,15,17,and 19 times 35
$\mu$Jy/beam.  An extra contour at 40.9 mJy/beam is added to show the
FWHP of the synthesized beam.

% \bibliographystyle{plain}
% \begin{thebibliography}{}


% \bibitem{} Clarke, D.A., Bridle, A.H., Burns, J.O.,
%     Perley, R.A., and Norman, M.L.,
% {\it Origin of the Structures and Polarization in the Classical
%    Double 3C219,\/}
% {{\it Ap.J.},\/{\bf 385}, 173--187, 1992}

%\end{thebibliography}

\end{document}
```

From: dclarke@chandra.harvard.edu (David Clarke)
To: abridle@polaris.cv.nrao.edu, rperley@aoc.nrao.edu
Cc: dclarke@chandra.harvard.edu
Subject: Re: Bow shocks
Date: Mon, 5 Oct 92 16:41:13 EDT

OK, here it comes. I am beginning to come around to dismiss the so-called compression model too. Despite everyone's valient attempts, I just hadn't appreciated the "power" of Doppler favouritism. At any rate, Alan brought up again - this time I heard it - the notion that there really is something still (apparently) feeding the southern hotspot. I look back in the 1991 paper that Jack and I put out which discusses the restarting jet scenario, and it seems to me we may be seeing part of that in 219. In this model, the old jet is *still* feeding the hotspot - we just gotta look! It's right there in that "extension" from S9 to the core that both CBBPN and BPH pointed out. When the old jet got cut off, as it were, a rarefaction wave travelled down the pipe at the jet speed plus the sound speed, which for highly supersonic velocities, is just v_jet. That takes a non-zero time to happen, during which time the hotspot is unaware that the jet has been turned off and thus remains bright and compact. Could this extension back to the core be that vestigal jet? And the edge-brightened features could be the rim of the now hollow cavity which once housed the jet. In time, this cavity will collapse onto itself, but in the meantime, it is filled with cold (the rarefaction wave acts like a rapid decompression, sapping the stuff of its energy), non-emitting stuff which should yield a centre-darkened region which once was the jet. Before the vistigal jet has completely emptied into the southern hotspot, the new jet is launched. As in Jack and my paper, this jet is launched into a rarefied, hot medium, with a high sound speed. The new jet may even be ballistic (denser than its immediate surroundings). Remember, its ambient is the old jet stuff - hotter and more rarefied for having passed thru the working surface. The new ballstic jet is not slowed (much) by the ambient, rendering a weak jet shock and a very bright (Doppler boosted) jet. Observationally, a weak jet shock may be supported by the fact that the tip of the jet isn't all *that* much brighter than the rest of the jet - at least not orders of magnitude (or is it? I forget what the new data say). Presumably the Mach disc is strong enough that on the CJ side, the tip slows enough to become visible.

Allow me the occasional "yes but..." if I feel the compression model deserves another gasp of breath here and there, but at this point, I see the above scenario as being quite inviting.

To answer Alan's other question directly, yes, I see X-shocks as a ubiquitous feature to be in trouble. I should point out, though, the same simulations show that terminal Mach discs are often not seen either. Instead, 3D jets seem to end in a series of oblique shocks. This may be telling us that we are not in the correct Mach number regime, and the Mach number which restores the integrity of Mach discs (if that is desirable) may also restore X-shocks. The jury is still out on that one.

You guys got a good sense of humour? Hope so, cause if my "revelations" are right, I could have been leading us all on a wild goose chase!

Cheers, David.