

Variability and jet motions in BL Lacertae object PKS 1413+135

Frank Ghigo, Yuri Y. Kovalev^{†,‡}, and Glen Langston

National Radio Astronomy Observatory, P.O. Box 2, Green Bank, WV 24944, U.S.A.

fghigo@nrao.edu; ykovalev@nrao.edu; glangsto@nrao.edu

ABSTRACT

The BL Lac object PKS 1413+135 was observed with the VLBA at several epochs in 2001 at three frequencies (5, 8.4, and 15.4 GHz) to study the compact double lobed radio structure. Significant variation is seen in the core flux on the time scale of a month, but little variation is seen in the jet structure on this scale. No shift in position of the base of the jet with frequency was found. The spectral index maps show an inverted spectrum for the core component and steep spectrum for the jet components. The core spectrum is separated from the total spectrum by subtracting a model determined at lower frequencies. This derived spectrum is in agreement with the measured core fluxes derived from our maps.

Subject headings: galaxies: active — galaxies: jets — radio continuum: galaxies — BL Lacertae objects: individual (PKS 1413+135)

1. Introduction

The well-known red BL Lac object PKS 1413+135 (see Perlman et al. 2002 for a review) exhibits much greater variability at higher frequencies ($\nu > 5$ GHz) than at lower frequencies, as seen by the Green Bank Interferometer monitoring program (Lazio et al. 2001). The variability indicates a very compact core, and this and its other unusual properties made it a good candidate for observations with space VLBI. Thus it was included in observations with the HALCA space VLBI satellite in 1996 through 1999 (Langston et al. 2000). A

[†]Jansky fellow, National Radio Astronomy Observatory

[‡]Also at Astro Space Center of Lebedev Physical Institute, Profsoyuznaya 84/32, 117997 Moscow, Russia

preliminary examination of the space VLBI observations suggested there were significant structural changes in the inner part of the western jet on time scales of less than a year. This motivated the VLBI observations reported here, undertaken to look for short term changes in structure, as well as to generally improve the understanding of this object.

PKS 1413+135 was classified as a BL Lac object due to its highly polarized near-IR continuum, line-less optical spectrum and extreme radio variability (Bregman et al. 1981, Beichmann et al. 1981, Stocke et al. 1992, Perlman et al. 1996). It is unique among BL Lacs in having a spiral host (McHardy et al. 1991, Stocke et al. 1992, Perlman et al. 2002). By comparison, “unified” theories for AGN associate BL Lacs with beamed FR 1 radio sources, found in giant elliptical galaxies (Urry & Padovani 1995). VLA observations reveal no kpc-scale structure to a dynamic range of 9600:1 (Perlman & Stocke 1994, Perlman et al. 1994). Under unified schemes this would indicate a highly beamed source, yet at mas scales PKS 1413+135 is clearly two-sided, indicating that it is seen close to the plane of the sky (Perlman et al. 1996). Thus this source presents a severe challenge to unified schemes.

The broadband spectrum of PKS 1413+135 shows a steep cutoff in the near-IR (Beichmann et al. 1981), and a heavily absorbed X-ray spectrum, yielding $N(H) > 2 \times 10^{22} \text{cm}^{-2}$ (Stocke et al. 1992). Redshifted 21 cm observations (Carilli et al. 1992) detected an absorbing column of $N(\text{HI}) = 1.3 \times 10^{19} (T_s/f) \text{cm}^{-2}$. Time-variable CO (J=1–0), HCO+ (J=2–1, 3–2), and HCN (J=1–2, 2–3) absorption has been detected by Wiklind & Combes (1991, 1994) suggesting that the AGN is behind a Giant Molecular Cloud (GMC) in the optical galaxy. VLBI observations in the redshifted 115 GHz CO line (Conway 1999) show an optical depth on the longest baselines (fringe spacing $\sim 70 \mu\text{as}$) approximately equal to that obtained with contemporaneous single-dish spectra, indicating the presence of extremely compact structure in the absorbing screen. Interestingly, there is no evidence that the extinguished AGN heats the absorbing gas, e.g. bright emission lines from a Narrow Line Region (NRL) or a mid-IR thermal continuum. To explain this dilemma, Perlman et al. (1994) and Stocke et al. (1992) proposed that the AGN is background to the observed galaxy and perhaps gravitationally lensed.

VLBA observations at 8.4 GHz Perlman et al. (1994, 1996) reveal complex two-sided structure. The bend in the Eastern jet is direct evidence for interactions with a dense nuclear medium. At 1.6, 2.3, and 5 GHz (Perlman et al. 1996) a mini-wide-angle-tail structure emerges, spanning $\sim 100 \text{mas}$.

Since the images do not show a second image or arc, they rule out macro-lensing, but not micro-lensing by a GMC in the optical galaxy (e.g., Narayan & Schneider 1990). The images are very similar to those of GPS and CSO such as 0710+439 and 2352+495 (Conway et al. 1992, Readhead et al. 1994), as noted by Perlman et al. (1994).

There are two possible explanations for these observed properties. One is that it is a very young source (see, e.g., Readhead et al. 1996, O’Dea & Baum 1997). Alternatively, it may be an older source frustrated by interactions with a dense confining medium. Readhead et al. (1994) have dismissed the latter possibility for 2352+495, since a frustrated source would require free-free absorption, which would quench the radio source below a few GHz, and excessive mass requirements within the inner 100 pc ($\sim 2 \times 10^{11} M_{\odot}$). The situation for PKS 1413+135 is similar, although the extreme steepness of the spectrum of the extended structure ($\alpha \sim 2$, Perlman et al. 1996) is tantalizing.

The redshift of PKS 1413+135 is 0.24681 (Darling 2004). We adopt a Hubble constant $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and a Friedmann–Robertson–Walker cosmology with $\Omega_m = 0.3$, $\Omega_{\Lambda} = 0.7$. For this cosmology, an angular size of 1 mas corresponds to 4.8 pc.

This paper presents new observations of PKS 1413+135 and compare the structure at three radio frequencies, 5, 8, and 15 GHz. VLBA observations and data processing are discussed in § 2. Modeling of the source structure is presented in § 3. Components identification and derived apparent speeds are presented in § 4. An analysis of a possible core shift with frequency is made in § 5. Spectral index images of the radiating material as well as total broad-band spectrum of the object are discussed in § 6. A helical jet fit to the structure is made in § 7. We summarize results in § 8.

2. Observations and Data Reduction

Observations were carried out at three frequency bands of 5, 8.4, and 15 GHz during three observing sessions (February 28, April 1, and April 30, 2001) using the 10-element VLBA¹. We observed using 1 bit samples in right and left circular polarization with a bit rate 128 Mbit/s. Parameters of the observations are summarized in Table 1. During each session, each of the three frequency bands were observed. The observations were organized into several 8 to 9.5 minute scans at each frequency. During the allotted 8 hours of observations, the three frequency bands were observed in alternation. The amplitude calibration source 3C 345 was observed at each frequency. No phase calibration sources were observed, since 1413+135 has a bright compact core. The data were correlated at the NRAO VLBA correlator in Socorro, NM. The correlator output contains 2 s integrations, each band with two IFs, 16 spectral channels per baseband.

¹Epoch of February 28: OV not used, recorder problems; April 1: HN not used because of snow/ice on the antenna; April 30: SC data lost.

Prior to hybrid imaging, all processing was performed in the NRAO Astronomical Image Processing System (AIPS; Greisen 2003). Sampler bias correction together with initial amplitude calibration was performed using the recorded system temperatures and gain tables (tasks “ACCOR” and “APCAL” through the “VLBACALA” procedure). Prior to fringe fitting, the supplied pulse calibration information was applied (task “PCCOR” through the “VLBAPCOR” procedure). Global fringe fitting was performed with the task FRING (through the “VLBAFRNG” procedure) to remove the remaining delay and rate errors, after choosing a stable, central reference antenna such as Pie Town (PT). A bandpass correction was then determined with the task BPASS. The data were then averaged across the channels within each IF. Editing in a station-based manner, additional flagging, self-calibration, and hybrid imaging was done using Caltech VLBI program DIFMAP (Shepherd, Pearson, & Taylor 1994, Shepherd 1999).

In addition to our three VLBA epochs in 2001, February–April, we have added two additional observations at 15 GHz to include with the analysis of jet motions. 1) VLBA plus phased VLA on 2001, January 4, in the framework of a project (Lister et al. (2003)) for phase calibration of a target source and 2) 2001, January 21, VLBA data collected for the 2 cm VLBA monitoring project² (Kellermann et al. 2004, hereafter K04). Table 2 lists the five epochs of 15 GHz data and indicates the number of antennas in each. Unfortunately no two epochs have exactly the same antenna configuration. Table 2 gives the beam dimensions showing how the resolution differs among the five epochs.

FITS CLEAN images as well as the flagged and calibrated complex visibility function data of the reduced VLBA observations for 1413+134 are available on-line³.

Cleaned images are displayed in Figure 1 for the three frequencies and three epochs. The peak and total clean fluxes for these maps are shown in Table 2. The lowest contour on all maps in Figure 1 is 0.4 mJy/beam, about three times the rms noise level.

One may readily see that the eastern jet has a somewhat steeper spectrum than the western jet, since it is very prominent at 5 GHz, but hardly detectable at 15 GHz. Discussion of the properties of individual components will follow in § 4 and 5, and of spectral index in § 7.

1–22 GHz total flux density broad-band spectrum of the objects was observed by us at the Russian 600 meter ring radio telescope RATAN–600 in the transit mode in the framework of an ongoing monitoring project (Kovalev 1998, Kovalev et al. 1999). Measurements at 31,

²<http://www.nrao.edu/2cmsurvey/>

³See electronic edition of the paper in *Astrophysical Journal*

13, 7.7, 3.9, 2.7, and 1.38 cm were done instantaneously (within 2 minutes) at all bands (see Kovalev et al. 1999 for details of method of observations, data processing and amplitude calibration).

3. Component fitting

Gaussian image plane components were fit using the Levenberg-Marquardt non-linear least squares minimization technique to the calibrated visibility data in the program DIFMAP. We first fit the core component at the location of the peak flux, subtracted this component, and fit components at the remaining major peaks. These were fit, subtracted, and the process repeated until no significant components were left and the RMS on the residual map was below about 0.4 mJy. The list of fitted parameters is given in Table 3. The fitting of components in this way is not unique. Choices are made in some cases to model a region by two components or by a single extended component. The choices were guided by reference to the appearance of the cleaned maps and by the desire to compare properties at the different epochs and different frequencies. Although the modeling is not unique, many alternative choices of component assignments were tried, and sets of components that fit the data badly become apparent because the model fitting did not converge. Thus the set of model components presented here are believed to be a faithful representation of the data. Any additional components that might be added would have to contain integrated flux densities of about one mJy or less.

Errors in the fitted parameters are estimated based on the discussion by Fomalont (1999). The error in integrated flux density of a component, S , is given by:

$$\Delta S = \sqrt{\left(S \frac{\Delta R}{P}\right)^2 + \Delta R^2 + (\Delta S)_{\text{cal}}^2}, \quad (1)$$

where ΔR — root-mean-square (RMS) flux density on the residual map at the component location, P — peak component’s intensity, $(\Delta S)_{\text{cal}}$ is the the amplitude calibration error. It is equal to about $0.05S$ according to our comparison with the total broad-band spectrum measured quasi-simultaneously with RATAN-600. It agrees with estimations presented by Wrobel & Ulvestad (2006) for a general 1–10 GHz VLBA flux density calibration accuracy.

The error in the component’s location, L , is given by:

$$\Delta L = \Delta R \frac{W}{2P}, \quad (2)$$

where W is the full width at half maximum (FWHM) of a Gaussian component. This is basically the width divided by signal-to-noise ratio. Since the fitted major axis, W , for some

components is very small (i.e., essentially a point) and since W appears in the equations for error in location, this may lead to unreasonably small estimates of position error. We have followed a suggestion based on an experience and analysis of the 2 cm VLBA survey group (private communication) and used 0.1 mas as the conservative minimum position error at λ 2 cm. Scaling to the other frequencies, we have used 0.2 mas at λ 3.6 cm and 0.3 mas at λ 6 cm.

The minimum detectable angular size (θ_{lim}) was calculated for each component using the following formula derived by Kovalev et al. (2005):

$$\theta_{lim} = b_{\psi} \sqrt{\frac{4 \ln 2}{\pi} \ln \left(\frac{SNR}{SNR - 1} \right)}. \quad (3)$$

where b_{ψ} is the half-power beam size measured along position angle ψ , and $SNR = \frac{P}{\Delta R}$. For the Gaussian components, we have calculated θ_{lim} for the position angles of the major and minor axes of the fitted component. If the major or minor axis is less than θ_{lim} then the value of θ_{lim} is given as an upper limit to the size in Table 3.

The model fitting results are given in Table 3. The components were designated ‘A’, ‘B’, and so forth, from east to west. Components ‘A’, ‘B’, and ‘C’ are the same as named by Perlman et al (1996). The western jet, called ‘D’ by Perlman et al.(1996), consists of several components, which we call ‘D1’, ‘D2’, ‘E1’, ‘E2’, ‘F1’, ‘F2’, ‘G’, and ‘H’. We use ‘K’ to refer to the core component, in which the peak flux of each map is located. A ridge of emission is seen extending from the core to the west towards component ‘E1’. We have modeled this ridge as one or two components designated ‘D1’ and ‘D2’.

In the counter-jet, component ‘A’ appears at 5 GHz as two parts which we call ‘A1’ ($\Delta\alpha \approx 33$ mas) and ‘A2’ ($\Delta\alpha \approx 27$ mas). But at 8.4 GHz, ‘A2’ does not appear, probably because it is more diffuse than ‘A1’. Neither part of ‘A’ is seen at 15.4 GHz. Component ‘B’ ($\Delta\alpha \approx 17$ mas) has consistent properties at for all epochs and frequencies. It is clearly double, as seen on the 8.4 GHz map, but we have modeled it as a single elliptical Gaussian.

In the region of component ‘C’, a single component (‘C2’) is seen at 15.4 GHz, two (‘C1’, ‘C2’) at 5 GHz, and three (‘C1’, ‘C2’, ‘C3’) are seen at 8.4 GHz.

4. Component Motions

Radial motions in the western jet were estimated by comparing the positions of components at the five epochs of 15.4 GHz observations (see Table 2). We have compared our data with kinematic results from the 15 GHz monitoring program (K04). In that paper, three

components in the western jet are designated ‘B’, ‘C’, and ‘F’, lying about 2.5, 4.5, and 7.5 mas from the core, respectively. These appear to correspond to components which we call ‘E2’, ‘F1’, and ‘G’, respectively.

The point component fit at the peak in the map is referred to as the “core”. The location of the core is in all cases only a few hundredths of a milliarcsecond from the mapping phase center position. The location of the core was subtracted from the location of each of the other components; thus all component locations are given relative to the core. The identification of the three components which we call ‘E2’, ‘F1’, and ‘G’ is shown in Figure 2.

The radial offsets from the core of the three components at the five epochs are plotted in Figure 3. Linear fits of location versus time were done for each component, and the results are listed in Table 4. One can see that the speeds of the components in the western jet are consistent with zero motion, i.e., we cannot detect any motion of these components over the four-month span of these observations.

The positions of the three components ‘E2’, ‘F1’, and ‘G’ were compared with the data presented by K04 which showed component positions observed over a six year span having speeds of 0.25 mas yr^{-1} for ‘E2’ (their ‘B’), 0.37 mas yr^{-1} for ‘F1’ (their ‘C’), and 0.45 mas yr^{-1} for ‘G’ (their ‘F’). In Figure 3 we show dashed lines indicating the position of components ‘E2’ and ‘G’ predicted by K04, based on the speed and zero point. They did not give a zero point for component ‘F’ because the fit was of poor quality. One can see (Table 4) that our results are consistent with those of K04 within the quoted errors.

5. Core shift analysis

The core component is most likely not at the position of the presumed black hole, but at the base of the jet, whose position may vary with frequency due to optical depth effects (see, e.g., Lobanov 1998). This effect has been sought in the present data by matching components ‘E2’, ‘F1’, and ‘G’ as fit to the 15 GHz data with the nearest components fit at the other two frequencies. These are the only components in the western jet that have counterparts at all three frequencies.

The offsets from the core as a function of frequency are plotted in Figure 4. The solid lines show linear least squares fits for each component, and fit parameters are listed in Table 5. The data show a significant shift with frequency for component ‘E2’.

If we were seeing a shift of the core position, then we would expect that all components would have the same position shift with frequency. But a significant shift is seen only in

component ‘E2’, thus we cannot be seeing a shift of the core, but only an effect of optical depth at that component. Thus we can place an upper limit on the core shift of three times the average one-sigma error, or about $0.045 \text{ mas GHz}^{-1}$ in the frequency range 5–15 GHz.

6. Spectral analysis

6.1. Spectral index images

We have constructed the two-frequency spectral index images for 5–8 and 8–15 GHz intervals (see Figure 5). As expected, the core region appears to be optically thick with optically thin jet features. A spectral aging is observed for the jet with spectral index α changing from -0.5 to -2 which corresponds to the evolution of the distribution of electrons energy with power γ from 2 to 5 assuming a powerlaw $N(E) = N_0 E^{-\gamma}$.

6.2. Component ‘C2’

An unusual gradient of spectral index is observed at 5–8 GHz spectral index images for the eastern jet component ‘C2’ (see zoomed ‘C2’ component spectral index imaged in Figure 6). This happens at all the tree of our multi-epoch experiments and exhibits itself also in a shift of the component’s centroid between 5 and 8 GHz. We explain this unusual phenomenon as an absorption by the same material as was detected in HI line observations by Perlman et al. (2002) in the central region of PKS 1413+135.

6.3. Total broad-band spectrum

Kovalev et al. (1999, 2002) suggested that total broad-band spectrum of almost all AGN could be modeled by a sum of two main spectral components: a slowly variable dominating at low frequencies optically thin emission of extended structure and dominating at high frequencies emission of compact structure of any kind of variability. We have modeled the low-frequency part of the spectrum according to this suggestion (Figure 7). The spectral index of the steep spectrum optically thin (in the examined region) emission of extended structure is found to be $\alpha = -0.64$, what gives an estimation of the index in the power law of the emitting particles energy distribution $\gamma = 2.28$.

We have incorporated data from the literature (Ulvestad et al. 1981, Perley 1982, Wright & Otrupcek 1990, Douglas et al. 1999, White et al. 1997, Condon et al. 1998) at frequencies

below 1.4 GHz to model with high accuracy the low frequency slowly variable part of the spectrum. The use of heterogeneous measurements made at different epochs is defensible by the confirmed assumption of slow variability in this spectral diapason.

Derived spectrum of a compact rapidly variable structure appeared to be optically thick with $\alpha = +1.6$ between 2 and 5 GHz. This value is much lower than predicted ($\alpha_{\text{tick}}^{\text{homog}} = +2.5$) one from a canonical spectrum of an homogeneous synchrotron source. We conclude that compact rapidly variable feature of the object is significantly more complex than a homogeneous case (geometrical shape and/or magnetic field distribution).

Both extended (on the level of $\sim 90\%$) and compact emission fall into the field of view of the VLBA in case of this object at observed frequencies. Our spectral index maps (Figure 5) and derived spectrum of the core region (Figure 7) confirm above discussion.

7. Jet helical structure

The observed structure of PKS 1413+135 has strong similarity to the spiral model described by Conway and Murphy (Conway & Murphy 1993). We have performed a constrained fit of the components of PKS 1413+135 to the model of (Conway & Murphy 1993).

7.1. Fit Constraints

In order to reduce the size of the parameters space searched, we have adopted the component velocity measured by Kellermann et al. (K04).

7.2. Numerical Simulations

The remaining free parameters of the Conway and Murphy model were fit by iteratively computing source models and comparing the models with the ridge-line fits to the source components. The goodness of fit measure was the integrated angular difference in the model and observed values. The fitting scheme was started by guesses to the parameters, then holding all but one parameter fixed and varying the final parameter until the best fit was found. Then that parameter was held fixed and the next parameter was varied. This process was repeated for all parameters.

After viewing the fit results and rejecting obviously erroneous fits, the entire process was repeated. The resulting model is shown in figure XXX.

The parameters fit are given in table ??? along with the range of parameters tested.

8. Summary

Five epochs of VLBI observations of PKS 1413+135 at 3 frequency bands are presented. These observations show the jet structure is changing slowly during this time, despite the very rapid changes in core brightness at 15 GHz. We have computed spectral index maps and fit the structure of the jet to the model of (Conway & Murphy 1993).

The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. We thank the VLBA staff for their dedication to providing high quality VLBI facilities. RATAN-600 observations were partly supported by the Russian State Program “Astronomy” and the Russian Ministry of Education and Science, the NASA JURRISS Program (project W-19611), and the Russian Foundation for Basic Research (projects 01-02-16812 and 05-02-17377). We have used VLBA calibrated visibility function data for PKS 1413+135 from the 2 cm VLBA monitoring program (e.g., K04) to supplement our observations during the beginning of 2001. The authors made use of the database CATS (Verkhodanov et al. 1997) of the Special Astrophysical Observatory. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

REFERENCES

- Aller, Margo F., Aller, Hugh D., Hughes, Philip A. & Latimer, George, 1999, ApJ, 512, 601
- Beichmann, C., Neugebauer, G., Soifer, B., Wooten, G., Roellig, T., & Harvey, P. 1981, Nature, 293, 711
- Bregman, J., Glassgold, A., Huggins, P., & Kinney, A. 1981, Nature, 293, 714.
- Carilli, C. L., Perlman, E. S., & Stocke, J. T. 1992, ApJ, 400, L13
- Condon, J. J., Cotton, W. D., Greisen, E. W., Yin, Q. F., Perley, R. A., Taylor, G. B., & Broderick, J. J. 1998, AJ, 115, 1693

- Conway, J. E. & Murphy, D. W. 1993, *ApJ*, 411, 89.
- Conway, J. E., 1999, *New Astronomy Reviews*, 43, 509.
- Conway, J. E., Pearson, T. J., & Readhead, A. C. S. 1992, *ApJ*, 396, 62
- Darling, Jeremy 2004, *ApJ*, 612, 58.
- Douglas, J. N., Bash, F. N., Bozyan, F. A., Torrence, G. W., & Wolfe, C. 1996, *AJ*, 111, 1945
- Fomalont, E. B. 1999. "Synthesis Imaging in Radio Astronomy", Taylor, Carilli, Perley, eds. ASP Conference Series 180, p301.
- Greisen, E. W. 2003, in *Astrophysics and Space Science Library* 285, *Information Handling in Astronomy – Historical Vistas*, ed. A. Heck (Dordrecht: Kluwer), 109
- Kellermann, K. I., & Pauliny-Toth, I. I. K. 1969, *ApJ*, 155, L31
- Kellermann, K. I., Lister, M. L., Homan, D. C., Vermeulen, R. C., Cohen, M. H., Ros, E., Kadler, M., Zensus, J. A., & Kovalev, Y. Y. 2004, *ApJ*, 609, 539 (K04)
- Kovalev, Yu. A. 1998, *Bull. SAO*, 44, 50
- Kovalev, Y. Y., Nizhelsky, N. A., Kovalev, Y. A., Berlin, A. B., Zhekanis, G. V., Mingaliev, M. G., & Bogdantsov, A. V. 1999, *A&AS*, 139, 545
- Kovalev, Y. Y., Kovalev, Yu. A., Nizhelsky, N. A., & Bogdantsov, A. V. 2002, *PASA*, 19, 83
- Kovalev, Y. Y., Kellermann, K. I., Lister, M. L., Homan, D. C., Vermeulen, R. C., Cohen, M. H., Ros, E., Kadler, M., Lobanov, A. P., Zensus, J. A., Kardashev, N. S., Gurvits, L. I., Aller, M. F., Aller, H. D. 2005, *AJ*, 130, 2473.
- Langston, G., Minter, A. H., Ghigo, F., 2000, *Adv. Space Res.* Vol. 26, p. 701.
- Lazio, T. J. W., Waltman, E. B., Ghigo, F. D., Fiedler, R. L., Foster, R. S., Johnston, K. J., 2001, *ApJS*, 136, 265.
- Lobanov, A. P. 1998, *A&A*, 330, 79
- Lister, M. L., Kellermann, K. I., Vermeulen, R. C., Cohen, M. H., Zensus, J. A., & Ros, E. 2003, *ApJ*, 584, 135
- McHardy, I. M., Abraham, R. G., Crawford, C. S., Ulrich, M.-H., Mock A. C., & Vander-speck, R. K. 1991, *MNRAS*, 249, 742

- McHardy, I. M., Merrifield, M. R., Abraham, R. G., & Crawford, C. S. 1994, MNRAS, 268, 681
- Narayan, R., & Schneider, P. 1990, MNRAS, 243, 192
- O’Dea, C. P., Baum, S. A., & Stanghellini, C. 1991, ApJ, 380, 66
- O’Dea, C. P., & Baum, S. A. 1997, AJ, 113, 1480
- O’Dea, C. P. 1998, PASP, 110, 493
- Perley, R. A. 1982, AJ, 87, 859
- Perlman, E. S., & Stocke, J. T. 1994, AJ, 108, 56
- Perlman, E. S., Stocke, J. T., Shaffer, D. B., Carilli, C., & Ma, C. 1994, ApJ, 424, 69
- Perlman, E. S., Carilli, C. L., Stocke, J. T., & Conway, J., 1996, AJ, 111, 1839
- Perlman, E. S., Stocke, J. T., Carilli, C. L., Sugiho, M., Madejski, G, Wang, Q. D., Conway, J. 2002, AJ, 124, 2401.
- Readhead, A. C. S., Xu, W., Pearson, T. J., Wilkinson, P. N., & Polatidis, A. 1994, in Compact Extragalactic Radio Sources, ed. J. A. Zensus, & K. I. Kellermann (Green Bank: NRAO), 17
- Readhead, A. C. S., et al. 1996, ApJ, 460, 612.
- Shepherd, M. C. 1997, in ASP Conf. Ser. 125, Astronomical Data Analysis Software and Systems VI, ed. G. Hunt, H. E. Payne (San Francisco: ASP), 77
- Shepherd, M. C., Pearson, T.J., & Taylor, G. B. 1994, BAAS, 26, 987
- Stevens, J. A., et al. 1994, ApJ437, 91.
- Stocke, J. T., Wurtz, R., Wang, Q. D., Jannuzi, B., & Elston, R. 1992, ApJ, 400, 17
- Ulvestad, J., Johnston, K., Perley, R., & Fomalont, E. 1981, AJ, 86, 1010
- Urry, M., & Padovani, P. 1995, PASP, 107, 803
- Verkhodanov, O. V., Trushkin, S. A., Andernach, H., & Chernenkov, V. N. 1997, in ASP Conf. Ser. 125, Astronomical Data Analysis Software and Systems VI, ed. by G. Hunt, & H. E. Payne (San Francisco: ASP), 322

- White, R. L., Becker, R. H., Helfand, D. J., & Gregg, M. D. 1997, ApJ, 475, 479
- Wiklind, T., & Combes, F. 1991, A&A, 328, 42
- Wiklind, T., & Combes, F. 1994, A&A, 286, L9
- Wilson, A., & Colbert, E. 1995, ApJ, 438, 62
- Wright, A., & Otrupcek, R. 1990, PKS90.C, 0000W
- Wrobel, J. M. & Ulvestad, J. S. 2006, VLBA Status Summary, NRAO;
<http://www.vlba.nrao.edu/astro/obstatus/current/obssum.html>

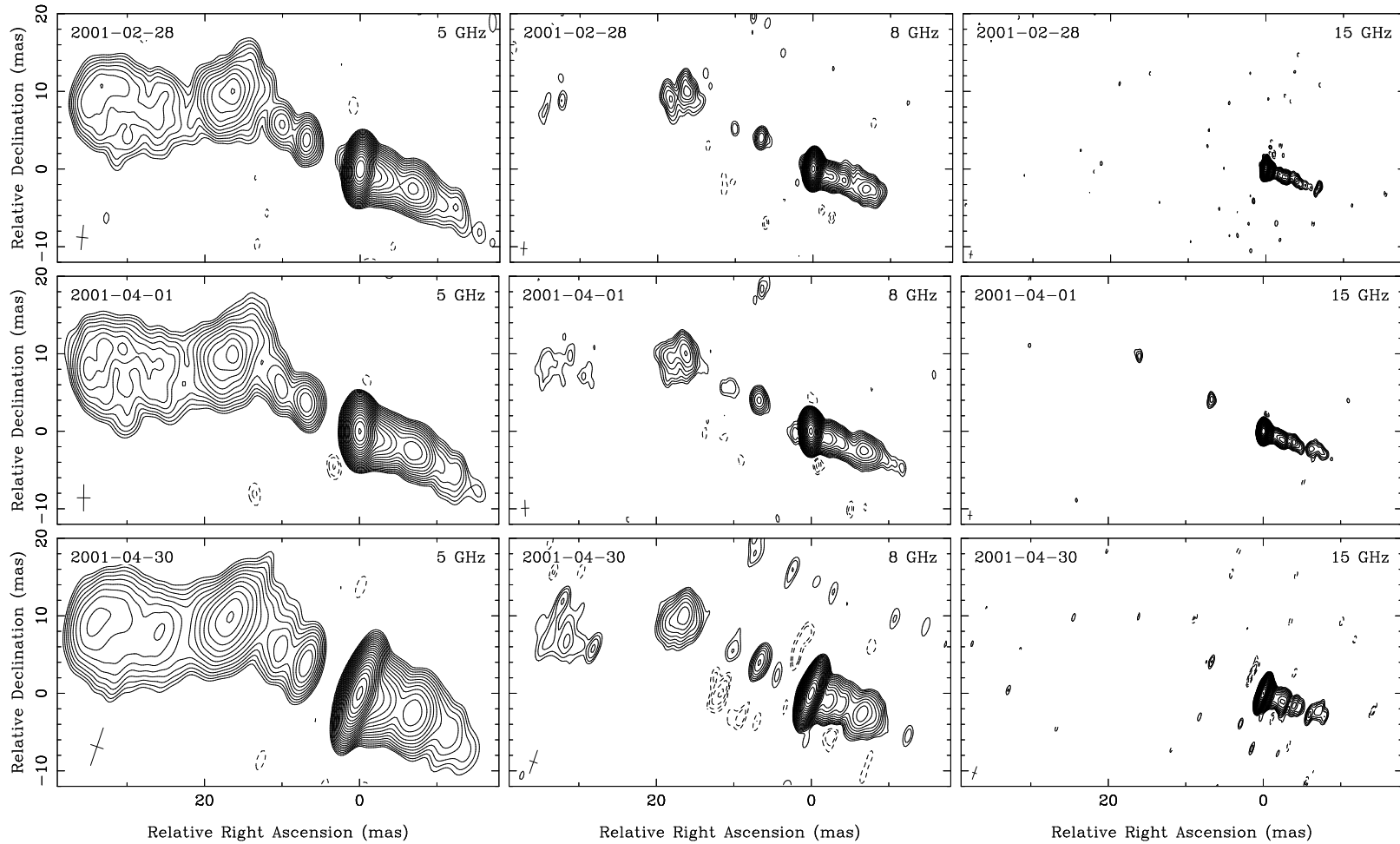


Fig. 1.— VLBA images of PKS 1413+135. The lowest contour is ± 0.4 mJy/beam, increasing by $\sqrt{2}$. See Table 2 for peaks and total fluxes. The UV and image FITS files are available on the web at ...

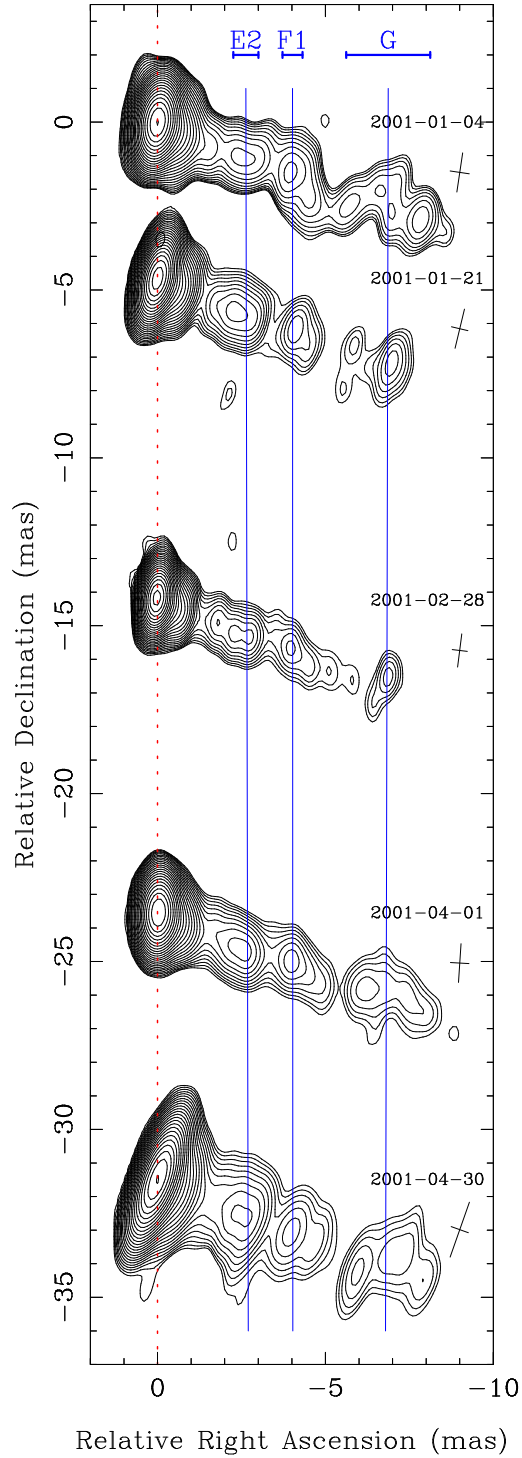


Fig. 2.— The jet evolution at 15 GHz. Five epochs are shown, from top to bottom. The HPBW of the clean beam for each map is shown on the right. Image parameters are presented in Table 2. Lines represent interpolated motion of modeled jet components. Map shift in relative declination is proportional to the time shift (approximately two mas per week or 100 mas per year.).

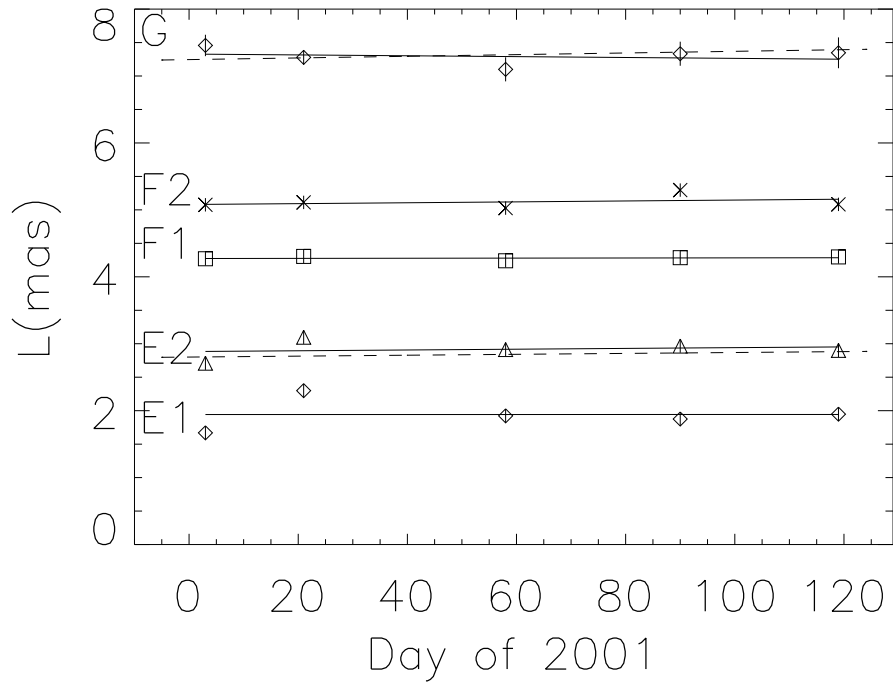


Fig. 3.— Positions as function of time for components ‘E1’, ‘E2’, ‘F1’, ‘F2’, and ‘G’. Solid lines are linear fits to the data points for each component. The horizontal dashed lines show the positions predicted by Kellermann et al. (2004). Refer to Table 4 for fit parameters.

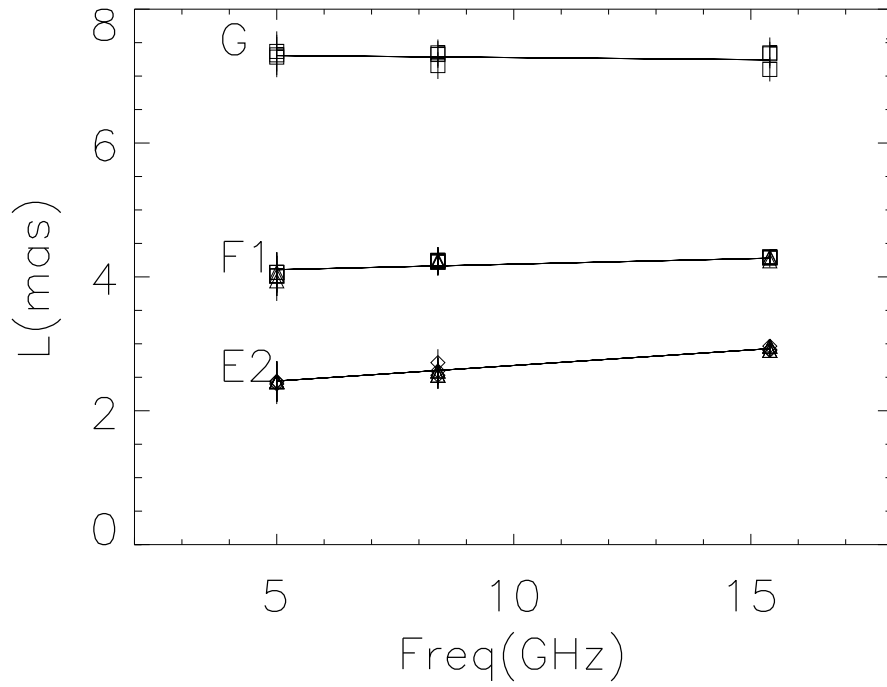


Fig. 4.— Offsets from core at three frequencies. Data from all three epochs are plotted. The solid lines are linear least squares fits. Refer to Table 5 for the fit parameters.

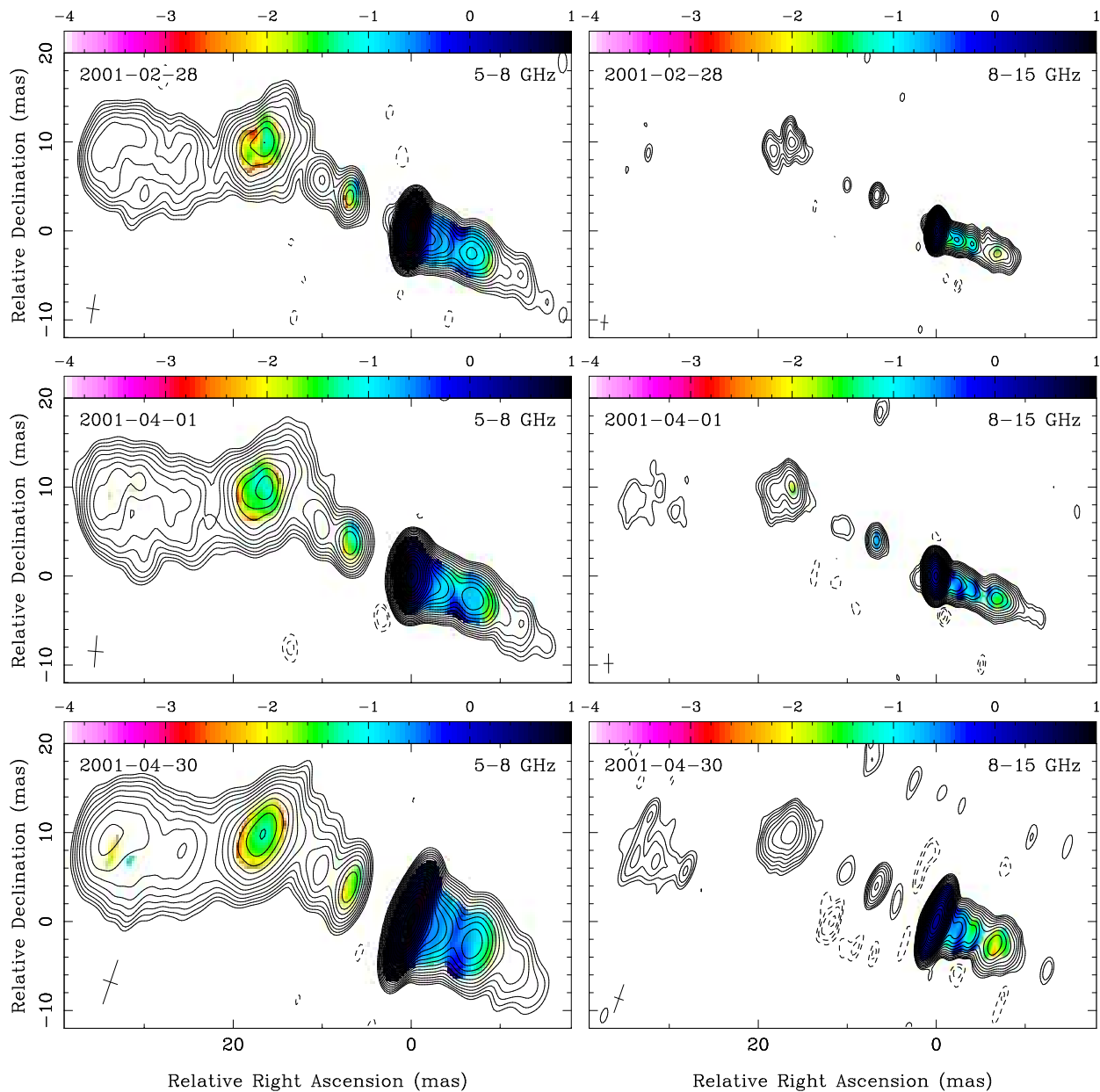


Fig. 5.— Spectral index maps of PKS 1413+135. Color represents spectral index values α ($S \sim \nu^\alpha$), contour maps are the lower frequency naturally weighted CLEAN images (see parameters in Table 2).

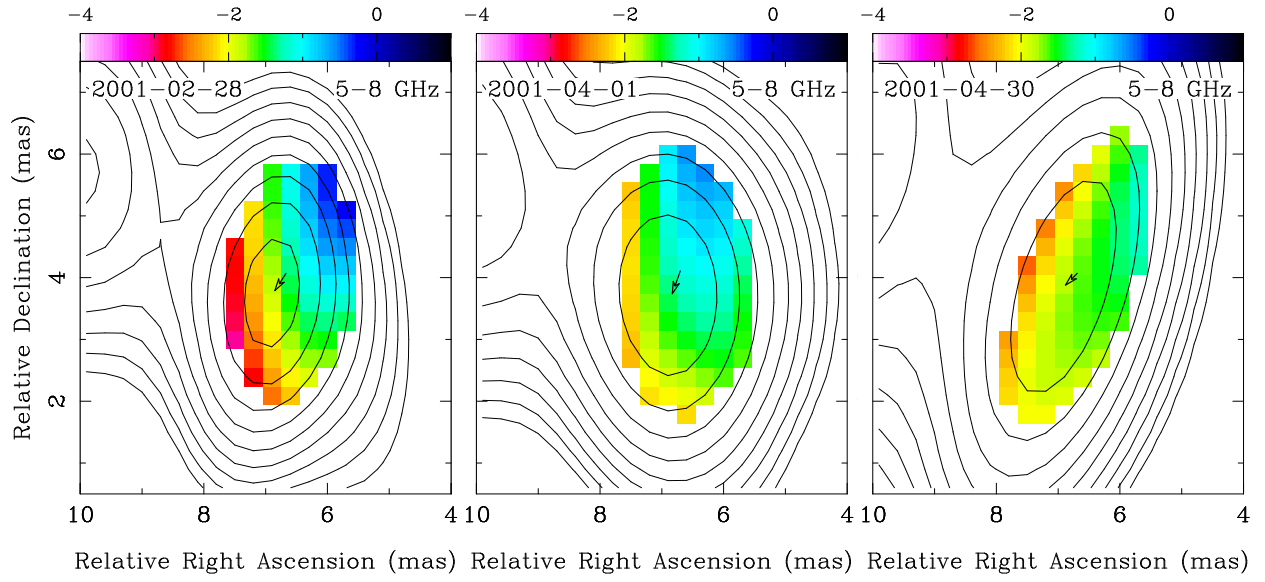


Fig. 6.— Spectral index maps of component C2 (zoomed from Figure 5). The arrows show the shift of the component’s centroid location from 8 to 5 GHz according to our modeling results (see Table 3).

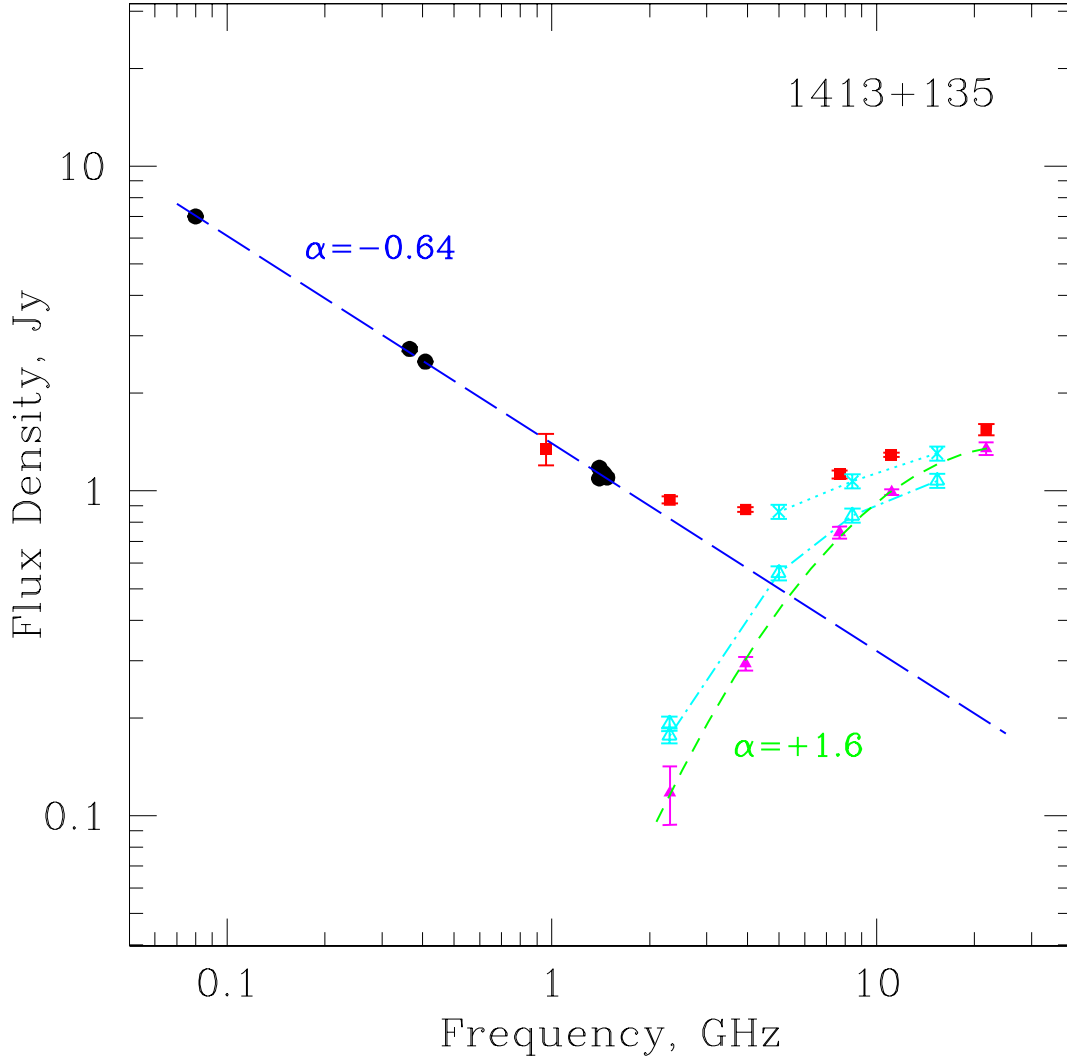


Fig. 7.— Broad-band spectrum of PKS 1413+135. Our RATAN-600 measurements made in March 28, 2001, are marked as squares, with 1σ error bars, low frequency (slow variable) data from the literature measured at other epochs by Ulvestad et al. (1981), Perley (1982), Wright & Otrupcek (1990), Douglas et al. (1999), White et al. (1997), Condon et al. (1998), are marked as circles. Steep spectrum ($\alpha = -0.64$) of an optically thin synchrotron radiation of extended structure is plotted by a long-dash line, it is least-square-fitted to data at $\nu < 1.5$ GHz. Subtraction of this spectrum from the data gives as a spectrum of a compact variable component of the source (triangles and fitted short-dash line) with spectral index $\alpha = +1.6$ of on optically thick part of the spectrum. Crosses and dotted line represent total CLEAN VLBA flux density on the epoch April 1, 2001.

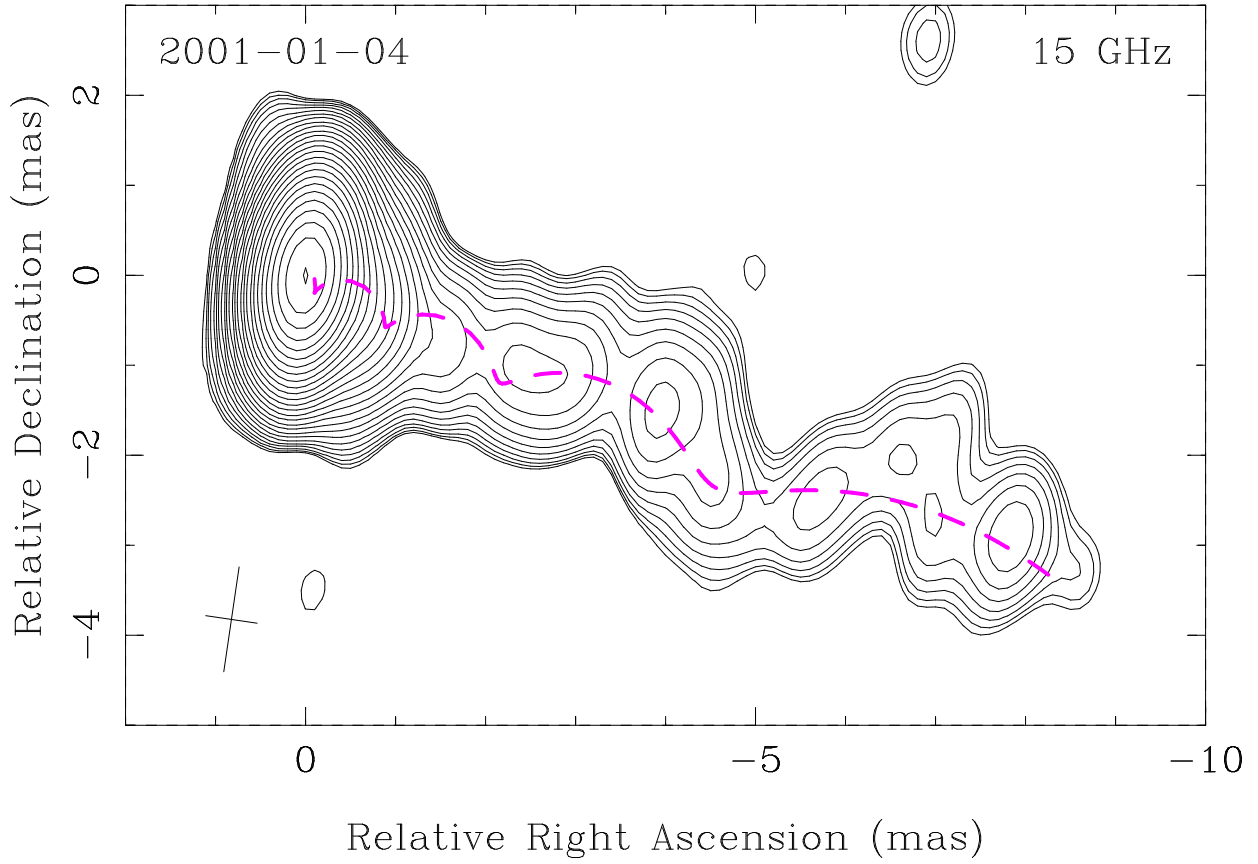


Fig. 8.— Modeling of the PKS 1413+135 15 GHz jet ridge line with a spiral.

Table 1. Observational parameters

| Frequency, MHz | Total bandwidth, MHz | Integration Time, min |
|------------------|----------------------|-----------------------|
| 15361.5, 15369.5 | 16 | 150 |
| 8417.5, 8425.5 | 16 | 125 |
| 4991.5, 4999.5 | 16 | 150 |

Note. — Quasi-simultaneous three-band VLBA measurements on Feb 28, Apr 01, and Apr 30 were done in both left and right circular polarization. Total bit-rate for each band: 128 Mbps.

Table 2. Parameters of the maps in Figures 1 and 2

| Epoch in 2001 (1) | Frequency (GHz) (2) | Antennas (3) | Beam (4) | Peak flux (Jy/beam) (5) | Total flux (Jy) (6) | Ref (7) |
|----------------------|------------------------|-----------------------------|--------------------------|----------------------------|------------------------|------------|
| Jan 04 | 15.4 | 9 + phased VLA ^a | 1.17×0.57 at -8° | 1.179 | 1.434 | L03 |
| Jan 22 | 15.4 | 10 | 1.20×0.50 at -14° | 1.453 | 1.599 | K04 |
| Feb 28 | 5.0 | 9 ^b | 3.19×1.48 at -6° | 0.579 | 0.828 | |
| | 8.4 | | 1.76×0.85 at -4° | 0.948 | 1.112 | |
| | 15.4 | | 0.99×0.45 at -7° | 1.339 | 1.489 | |
| Apr 01 | 5.0 | 9 ^c | 3.41×1.68 at -1° | 0.598 | 0.863 | |
| | 8.4 | | 2.07×1.01 at 2° | 0.916 | 1.071 | |
| | 15.4 | | 1.15×0.55 at -4° | 1.154 | 1.306 | |
| Apr 30 | 5.0 | 9 ^d | 5.12×1.72 at -19° | 0.634 | 0.891 | |
| | 8.4 | | 3.15×1.05 at -19° | 1.006 | 1.160 | |
| | 15.4 | | 1.73×0.54 at -19° | 1.184 | 1.327 | |

Note. — Col. (1): epoch of observation. Col. (2): central frequency (GHz). Col. (3): number of VLBA antennas. Col. (4): beam parameters: major and minor HPBW (mas), P.A. of the major axis (degrees). Col. (5): peak flux density of a CLEAN naturally weighted image (Jy/beam). Col. (6): integrated flux density of a CLEAN naturally weighted image calculated as a sum of CLEAN components (Jy). Col. (7): Data reference if different from this paper: L03: Lister et al. (2003), K04: Kellermann et al. (2004). The lowest contour on all maps is ± 0.4 mJy/beam, except for the Jan 04 map for which it is ± 0.2 mJy/beam. The interval between contours is a factor of $\sqrt{2}$, up to the peak value listed in this table.

^aNL not used.

^bOV not used.

^cHN not used.

^dSC not used.

Table 3. Fitted parameters of components.

| Component (1) | Band (2) | Epoch (3) | Flux (4) | $\Delta\alpha, \Delta\delta, (\sigma_p)$ (5) | Major(mas) (6) | Minor (7) | PA (8) |
|------------------|-------------|--------------|---------------|---|---------------------|--------------|-----------|
| K (core) | 15.4 | Jan 04 | 1166.6 ± 58.3 | ... | 0.08 | ... | ... |
| | | Jan 22 | 1439.5 ± 72.0 | ... | 0.06 | ... | ... |
| | | Feb 28 | 1328.1 ± 66.4 | ... | 0.05 | ... | ... |
| | | Apr 01 | 1076.8 ± 53.8 | ... | 0.05 | ... | ... |
| | | Apr 30 | 1098.1 ± 54.9 | ... | < 0.04 | ... | ... |
| | 8.4 | Feb 28 | 944.9 ± 47.3 | ... | 0.14 | ... | ... |
| | | Apr 01 | 839.8 ± 42.0 | ... | < 0.02 | ... | ... |
| | | Apr 30 | 949.7 ± 47.5 | ... | 0.09 | ... | ... |
| | 5.0 | Feb 28 | 544.0 ± 27.2 | ... | 0.11 | ... | ... |
| | | Apr 01 | 558.1 ± 27.9 | ... | < 0.05 | ... | ... |
| Apr 30 | | 602.3 ± 30.1 | ... | 0.21 | ... | ... | |
| A1 | 8.4 | Feb 28 | 18.2 ± 4.1 | 31.75 8.85 (± 1.04) | 9.50 | 6.23 | 68 |
| | | Apr 01 | 18.6 ± 3.5 | 31.01 8.56 (± 0.91) | 10.06 | 6.64 | 76 |
| | | Apr 30 | 24.4 ± 5.2 | 30.90 7.64 (± 1.00) | 9.61 | 6.86 | 59 |
| | 5.0 | Feb 28 | 27.8 ± 2.9 | 33.33 9.95 (± 0.31) | 6.90 | 4.22 | –38 |
| | | Apr 01 | 32.6 ± 4.1 | 33.78 9.32 (± 0.43) | 7.48 | 4.30 | –20 |
| | | Apr 30 | 30.6 ± 2.3 | 33.49 9.77 (± 0.30) | 6.82 | 4.53 | –37 |
| A2 | 5.0 | Feb 28 | 53.3 ± 7.1 | 27.44 6.98 (± 0.72) | 11.63 | 8.21 | –89 |
| | | Apr 01 | 50.4 ± 11.1 | 26.97 7.22 (± 1.06) | 9.91 | 8.56 | 51 |
| | | Apr 30 | 51.0 ± 4.8 | 26.97 7.25 (± 0.44) | 11.17 | 7.76 | –75 |
| B | 15.4 | Jan 04 | 13.7 ± 2.9 | 16.71 9.87 (± 0.54) | 5.19 | 3.75 | 83 |
| | | Jan 22 | 3.8 ± 1.3 | 16.28 9.96 (± 1.09) | 6.41 | < 0.41 | 34 |
| | | Feb 28 | 16.3 ± 4.5 | 17.81 9.60 (± 1.00) | 7.40 | 4.10 | 42 |
| | | Apr 01 | 8.7 ± 1.9 | 16.69 9.65 (± 0.38) | 3.62 | 3.16 | –51 |
| | | Apr 30 | 9.6 ± 2.8 | 16.88 9.96 (± 0.88) | 6.15 | 3.92 | 73 |
| | | 8.4 | Feb 28 | 25.1 ± 2.9 | 16.72 9.74 (± 0.21) | 4.18 | 2.92 |
| | Apr 01 | | 29.5 ± 2.8 | 16.83 9.63 (± 0.20) | 4.36 | 3.39 | –36 |
| | Apr 30 | | 28.4 ± 2.1 | 16.66 9.65 (± 0.20) | 4.02 | 3.04 | –54 |
| | 5.0 | Feb 28 | 61.6 ± 3.9 | 16.74 9.73 (± 0.30) | 5.02 | 3.83 | –37 |
| | | Apr 01 | 68.0 ± 4.7 | 16.79 9.64 (± 0.30) | 5.43 | 4.21 | –37 |
| | | Apr 30 | 61.4 ± 3.3 | 16.77 9.67 (± 0.30) | 5.15 | 3.72 | –38 |
| | C1 | 8.4 | Feb 28 | 2.6 ± 0.4 | 10.22 5.10 (± 0.20) | 2.01 | 1.30 |
| Apr 01 | | | 3.9 ± 0.4 | 10.66 5.40 (± 0.20) | 2.10 | 1.59 | 28 |
| Apr 30 | | | 3.6 ± 0.6 | 10.35 5.38 (± 0.20) | 2.66 | < 0.90 | 54 |
| 5.0 | | Feb 28 | 10.8 ± 1.1 | 9.96 5.90 (± 0.30) | 4.78 | 2.84 | –22 |
| | | Apr 01 | 10.8 ± 1.1 | 10.13 6.04 (± 0.30) | 4.91 | 2.54 | –15 |
| | | Apr 30 | 13.7 ± 1.0 | 10.15 6.22 (± 0.30) | 5.62 | 3.93 | 15 |
| C2 | 15.4 | Jan 04 | 8.6 ± 2.2 | 7.22 4.02 (± 0.58) | 4.64 | 2.00 | 59 |
| | | Jan 22 | 2.9 ± 0.8 | 7.01 4.32 (± 0.13) | 1.17 | < 0.30 | –56 |
| | | Feb 28 | 3.3 ± 0.9 | 6.89 4.00 (± 0.18) | 1.36 | 0.93 | 69 |

Table 3—Continued

| Component (1) | Band (2) | Epoch (3) | Flux (4) | $\Delta\alpha, \Delta\delta, (\sigma_p)$ (5) | Major(mas) (6) | Minor (7) | PA (8) |
|------------------|-------------|--------------|-----------------|---|-------------------|--------------|-----------|
| | | Apr 01 | 4.2 ± 0.5 | 6.61 4.02 (± 0.10) | 1.77 | 0.46 | 8 |
| | | Apr 30 | 3.8 ± 0.8 | 6.81 3.97 (± 0.21) | 2.15 | 0.87 | 24 |
| | 8.4 | Feb 28 | 4.6 ± 0.5 | 6.67 4.07 (± 0.20) | 0.73 | 0.63 | –73 |
| | | Apr 01 | 5.6 ± 0.4 | 6.70 4.11 (± 0.20) | 0.92 | 0.52 | –77 |
| | | Apr 30 | 5.0 ± 0.4 | 6.69 4.07 (± 0.20) | 1.34 | < 0.33 | –65 |
| | 5.0 | Feb 28 | 11.5 ± 0.7 | 6.85 3.79 (± 0.30) | 1.50 | 0.72 | 56 |
| | | Apr 01 | 13.9 ± 0.9 | 6.83 3.74 (± 0.30) | 1.85 | 1.07 | 41 |
| | | Apr 30 | 11.3 ± 0.7 | 6.88 3.88 (± 0.30) | 1.82 | < 0.35 | 30 |
| C3 | 8.4 | Apr 01 | 1.8 ± 0.4 | 4.45 1.87 (± 0.27) | 2.71 | < 0.46 | 19 |
| | | Apr 30 | 2.7 ± 0.4 | 4.41 2.13 (± 0.20) | 2.68 | < 0.41 | 9 |
| D1 | 15.4 | Jan 04 | 74.4 ± 3.8 | –0.35 –0.12 (± 0.10) | 0.14 | ... | ... |
| | | Jan 22 | 83.9 ± 4.3 | –0.33 –0.14 (± 0.10) | < 0.10 | ... | ... |
| | | Feb 28 | 100.3 ± 5.2 | –0.29 –0.13 (± 0.10) | 0.11 | ... | ... |
| | | Apr 01 | 151.7 ± 7.6 | –0.25 –0.12 (± 0.10) | 0.15 | ... | ... |
| | | Apr 30 | 151.8 ± 7.6 | –0.24 –0.11 (± 0.10) | < 0.10 | ... | ... |
| | 8.4 | Feb 28 | 73.0 ± 3.7 | –0.54 –0.24 (± 0.20) | < 0.07 | ... | ... |
| | | Apr 01 | 121.7 ± 6.1 | –0.41 –0.19 (± 0.20) | 0.17 | ... | ... |
| | | Apr 30 | 103.8 ± 5.2 | –0.44 –0.20 (± 0.20) | < 0.05 | ... | ... |
| D2 | 15.4 | Jan 04 | 45.8 ± 2.4 | –0.73 –0.38 (± 0.10) | 0.36 | ... | ... |
| | | Jan 22 | 43.6 ± 2.4 | –0.68 –0.35 (± 0.10) | 0.24 | ... | ... |
| | | Feb 28 | 40.1 ± 2.4 | –0.66 –0.36 (± 0.10) | 0.21 | ... | ... |
| | | Apr 01 | 38.9 ± 2.1 | –0.65 –0.32 (± 0.10) | 0.22 | ... | ... |
| | | Apr 30 | 46.6 ± 2.5 | –0.64 –0.33 (± 0.10) | 0.47 | ... | ... |
| | 5.0 | Feb 28 | 67.2 ± 3.4 | –0.67 –0.30 (± 0.30) | < 0.18 | ... | ... |
| | | Apr 01 | 63.8 ± 3.2 | –0.67 –0.32 (± 0.30) | < 0.15 | ... | ... |
| | | Apr 30 | 58.1 ± 2.9 | –0.68 –0.30 (± 0.30) | 0.44 | ... | ... |
| E1 | 15.4 | Jan 04 | 9.0 ± 0.8 | –1.48 –0.77 (± 0.10) | 0.48 | ... | ... |
| | | Jan 22 | 13.9 ± 1.4 | –2.12 –0.89 (± 0.10) | 0.69 | ... | ... |
| | | Feb 28 | 9.7 ± 1.6 | –1.77 –0.75 (± 0.10) | 0.68 | ... | ... |
| | | Apr 01 | 13.2 ± 1.4 | –1.74 –0.70 (± 0.10) | 0.92 | ... | ... |
| | | Apr 30 | 10.0 ± 1.3 | –1.81 –0.72 (± 0.10) | 0.84 | ... | ... |
| | 8.4 | Feb 28 | 17.3 ± 1.2 | –1.37 –0.74 (± 0.20) | 0.76 | ... | ... |
| | | Apr 01 | 10.6 ± 0.6 | –1.06 –0.55 (± 0.20) | < 0.25 | ... | ... |
| | | Apr 30 | 13.9 ± 0.9 | –1.04 –0.58 (± 0.20) | 0.56 | ... | ... |
| E2 | 15.4 | Jan 04 | 13.0 ± 1.2 | –2.51 –1.02 (± 0.10) | 0.82 | ... | ... |
| | | Jan 22 | 7.3 ± 1.0 | –2.83 –1.26 (± 0.10) | 0.50 | ... | ... |
| | | Feb 28 | 12.7 ± 1.6 | –2.65 –1.21 (± 0.10) | 0.73 | ... | ... |
| | | Apr 01 | 11.3 ± 1.1 | –2.68 –1.27 (± 0.10) | 0.58 | ... | ... |
| | | Apr 30 | 12.7 ± 1.2 | –2.65 –1.18 (± 0.10) | 0.75 | ... | ... |
| | 8.4 | Feb 28 | 20.4 ± 1.4 | –2.50 –1.07 (± 0.20) | 0.87 | ... | ... |

Table 3—Continued

| Component (1) | Band (2) | Epoch (3) | Flux (4) | $\Delta\alpha, \Delta\delta, (\sigma_p)$ (5) | Major(mas) (6) | Minor (7) | PA (8) |
|------------------|-------------|--------------|----------------|---|-------------------|--------------|-----------|
| | | Apr 01 | 26.6 ± 1.5 | $-2.32 -1.01 (\pm 0.20)$ | 1.06 | ... | ... |
| | | Apr 30 | 24.9 ± 1.4 | $-2.39 -1.01 (\pm 0.20)$ | 1.10 | ... | ... |
| | 5.0 | Feb 28 | 30.1 ± 1.6 | $-2.20 -0.96 (\pm 0.30)$ | 0.86 | ... | ... |
| | | Apr 01 | 30.0 ± 1.5 | $-2.20 -1.04 (\pm 0.30)$ | 0.83 | ... | ... |
| | | Apr 30 | 31.7 ± 1.6 | $-2.24 -0.97 (\pm 0.30)$ | 1.05 | ... | ... |
| F1 | 15.4 | Jan 04 | 6.2 ± 0.8 | $-4.03 -1.41 (\pm 0.10)$ | 0.63 | ... | ... |
| | | Jan 22 | 4.4 ± 0.6 | $-4.06 -1.43 (\pm 0.10)$ | 0.47 | ... | ... |
| | | Feb 28 | 6.2 ± 0.8 | $-3.98 -1.46 (\pm 0.10)$ | 0.78 | ... | ... |
| | | Apr 01 | 6.7 ± 0.5 | $-4.04 -1.43 (\pm 0.10)$ | 0.60 | ... | ... |
| | | Apr 30 | 4.3 ± 0.4 | $-4.00 -1.57 (\pm 0.10)$ | 0.57 | ... | ... |
| | 8.4 | Feb 28 | 10.0 ± 0.9 | $-3.94 -1.51 (\pm 0.20)$ | 0.90 | ... | ... |
| | | Apr 01 | 10.9 ± 0.8 | $-3.98 -1.48 (\pm 0.20)$ | 0.90 | ... | ... |
| | | Apr 30 | 8.9 ± 0.6 | $-3.95 -1.50 (\pm 0.20)$ | 0.58 | ... | ... |
| | 5.0 | Feb 28 | 17.4 ± 1.0 | $-3.66 -1.46 (\pm 0.30)$ | 1.06 | ... | ... |
| | | Apr 01 | 19.1 ± 1.0 | $-3.74 -1.46 (\pm 0.30)$ | 0.97 | ... | ... |
| | | Apr 30 | 16.4 ± 0.8 | $-3.80 -1.45 (\pm 0.30)$ | 1.04 | ... | ... |
| F2 | 15.4 | Jan 04 | 2.4 ± 0.5 | $-4.52 -2.31 (\pm 0.10)$ | < 0.23 | ... | ... |
| | | Jan 22 | 1.9 ± 0.6 | $-4.70 -2.01 (\pm 0.10)$ | 0.39 | ... | ... |
| | | Feb 28 | 1.6 ± 0.4 | $-4.53 -2.18 (\pm 0.10)$ | < 0.19 | ... | ... |
| | | Apr 01 | 1.5 ± 0.3 | $-4.77 -2.30 (\pm 0.10)$ | 0.30 | ... | ... |
| | | Apr 30 | 1.5 ± 0.2 | $-4.73 -1.86 (\pm 0.10)$ | < 0.20 | ... | ... |
| G | 15.4 | Jan 04 | 12.6 ± 1.7 | $-6.97 -2.65 (\pm 0.16)$ | 2.47 | 1.27 | 75 |
| | | Jan 22 | 9.8 ± 1.6 | $-6.81 -2.57 (\pm 0.11)$ | 1.52 | 1.32 | -29 |
| | | Feb 28 | 12.4 ± 1.9 | $-6.66 -2.46 (\pm 0.18)$ | 2.46 | 1.60 | 84 |
| | | Apr 01 | 14.3 ± 1.9 | $-6.89 -2.51 (\pm 0.18)$ | 2.89 | 1.40 | 66 |
| | | Apr 30 | 13.1 ± 2.2 | $-6.89 -2.55 (\pm 0.23)$ | 2.97 | 1.55 | 87 |
| | 8.4 | Feb 28 | 26.5 ± 1.8 | $-6.86 -2.56 (\pm 0.20)$ | 3.18 | 1.78 | 69 |
| | | Apr 01 | 25.7 ± 1.5 | $-6.86 -2.63 (\pm 0.20)$ | 2.75 | 1.64 | 75 |
| | | Apr 30 | 26.1 ± 1.7 | $-6.64 -2.67 (\pm 0.20)$ | 2.83 | 1.68 | 63 |
| | 5.0 | Feb 28 | 35.8 ± 1.9 | $-6.80 -2.61 (\pm 0.30)$ | 3.31 | 1.13 | 70 |
| | | Apr 01 | 36.6 ± 1.9 | $-6.91 -2.56 (\pm 0.30)$ | 3.11 | 1.15 | 65 |
| | | Apr 30 | 34.6 ± 1.8 | $-6.84 -2.60 (\pm 0.30)$ | 3.08 | < 0.43 | 65 |
| H | 8.4 | Apr 01 | 2.8 ± 0.4 | $-11.23 -4.41 (\pm 0.20)$ | 2.26 | 0.96 | 46 |
| | | Apr 30 | 4.3 ± 1.0 | $-11.81 -5.16 (\pm 0.69)$ | 6.20 | < 1.28 | 59 |
| | 5.0 | Feb 28 | 9.0 ± 1.3 | $-11.29 -5.18 (\pm 0.42)$ | 6.17 | 3.03 | 50 |
| | | Apr 01 | 8.6 ± 0.9 | $-11.57 -5.44 (\pm 0.30)$ | 5.33 | 2.75 | 48 |
| | | Apr 30 | 9.5 ± 1.0 | $-11.37 -5.10 (\pm 0.32)$ | 6.88 | 2.96 | 42 |

Note. — Col. (1): Component label. Col. (2): Frequency (GHz). Col. (3): Epoch in 2001. Col. (4): Integrated component flux density and error (mJy). Col. (5): Offset from core ('K') component and error (mas). Col. (6): Major axis of fitted component (mas). Col. (7): Axial ratio. Col. (8): Position angle (degrees). Components: core: K; eastern jet: A1, A2, B, C1, C2, C3; western jet: D1, D2, E1, E2, F1, F2, G, H.

Table 4. Component speeds (mas/year) – slope of fitted line.

| Component | Speed (mas/year) | K04 Name | K04 Speed | K04 v/c |
|-----------|------------------|----------|-----------------|---------------|
| E1 | 0.00 ± 0.38 | | | |
| E2 | 0.21 ± 0.38 | B | 0.25 ± 0.08 | 3.9 ± 1.2 |
| F1 | 0.04 ± 0.38 | C | 0.37 ± 0.15 | 5.8 ± 2.4 |
| F2 | 0.24 ± 0.38 | | | |
| G | -0.23 ± 0.68 | F | 0.45 ± 0.15 | 7.1 ± 2.4 |

Note. — Col. (2) gives the result of the linear fits to the data shown in Figure 3. Cols. (3), (4), and (5) show the parameters for these components in K04: component name, angular speed, and apparent velocity (v/c). We note that our apparent speeds are in agreement with those of K04 within the quoted errors.

Table 5. Fits for core shift versus frequency.

| Component | Slope (mas/GHz) |
|-----------|--------------------|
| E2 | 0.046 ± 0.014 |
| F1 | 0.016 ± 0.014 |
| G | -0.006 ± 0.018 |

Note. — Model results from Feb 28, Apr 01, and Apr 30, 2001, are used together for this fit.