Milliarcsecond-Scale Structure in the Gamma-Ray Loud Quasar PKS 1622-297

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Abstract

PKS 1622-297 is the most luminous gamma-ray emitting active galactic nucleus (AGN) ever detected and showing gamma-ray intraday variability (IDV). We have made a high-resolution space VLBI observation of the source almost three years after the gamma-ray IDV. The source shows a compact core-jet structure and all jet components have an apparent superluminal motion up to 12.1 h^{-1} c. As an alter- native probe of the sub-parsec scale structure, we also present the results from multi-epoch ATCA total flux monitoring, which indicate the presence of intraday variability at both 4.8 and 8.6 GHz. We examine the inner structure of the gamma-ray emitting AGN in the light of these observations.

Introduction

- General properties of PKS 1622-297
  - Redshift: z = 0.815 (1 mas = 5.3 h^{-1} pc)
  - Gamma-ray emitted AGN detected by EGRET (Hartman et al. 1999)
  - Rapid gamma-ray variability by a factor of 3.6 in less than 7.1 hours (Mattox et al. 1997; see Fig. 1)
  - Reported to displaying intraday variability (IDV) feature at 8.6 GHz (Kedziora-Chudczer et al. 2001)
  - Well-sampled AGN in terms of gamma-ray flux monitoring and VLBI observations (e.g. Jorstad et al. 2001; see Fig. 2)

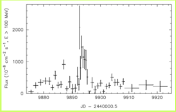


Figure 1: Gamma-ray light curve for PKS 1622-297 at an intensive flare on 1995.48 observed by EGRET (Mattox et al. 1997).

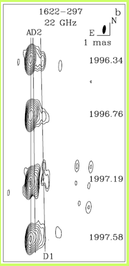
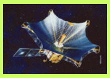


Figure 2: Hybrid VLBI images of PKS 1622-297 at 22 GHz. Component A is assumed as a core and components D2 and D1 as jets (Jorstad et al. 2001).

- Purpose of this work
  - Physical properties of a gamma-ray emitting region in AGN
  - Compactness of the innermost region of AGN measuring the core size by VLBI and short-time variability by total flux monitoring
  - Jet properties in terms of the apparent speed, the Doppler factor, and the jet viewing angle
  - Relationship between gamma-ray emission and ejection of a new jet component

Observations

- Space VLBI (VSOP) observation
  - Date: 1998 February 22 22:00 – 27:00
  - Radio telescopes: HALCA spacecraft (8 m diameter), Shanghai 25 m (China), Hobart 26m (Australia), Hartebeesthoek 26 m (South Africa)
  - Observation frequency: 5 GHz
  - Data calibration, imaging, and model fitting: NRAO AIPS and Caltech Difmap



- ATCA (Australia Telescope Compact Array, 6x22 m) total flux monitoring
  - Date: 2001 February 4 – 2002 February 21 (10 epochs in total)
  - Observation frequency: 4.8 GHz, 8.6 GHz
  - Data reduction: MIRIAD
  - Observations were carried out as part of ATCA IDV survey (Kedziora-Chudczer et al. 2001)

Results of VSOP Observation

- Parsec-scale structure
  - Compact core and two jet components toward west (see Fig. 3)
  - Two jet components have superluminal motion (see Fig. 4)
- Brightness temperature and derived Doppler factor of the core

$$T_B = (3.73 \pm 0.07)\times 10^{11} \quad \mathrm{K}, \quad \delta = 2.45 \pm 0.05$$

- Proper motion and viewing angle obtained from the Doppler factor and the proper motion (see Table 1)

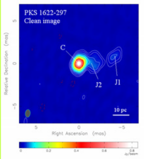


Figure 3: VSOP Image of PKS 1622-297. Contour levels are 9.5 X (-1, 1, 2, 4, …, and 64) mJy beam^{-1}, and the peak flux density is 0.84 Jy beam^{-1}.

Table 1: Apparent proper motion and viewing angle of each component

Component	Proper motion $[\mathrm{mas\ yr^{-1}}]$	Apparent velocity	Ejection epoch [yr]	Viewing angle [deg]
J1	0.70 ± 0.11	$(12.1 \pm 1.9)h^{-1}c$	1992.39 ± 0.73	$6^\circ.9 \pm 1^\circ.1$
J2	0.34 ± 0.02	$(5.9 \pm 0.3)h^{-1}c$	1994.25 ± 0.10	$13^\circ.2 \pm 0^\circ.6$
B2+D2+E3	0.13 ± 0.01	$(2.2 \pm 0.2)h^{-1}c$	1994.94 ± 0.08	$23^\circ.3 \pm 0^\circ.7$

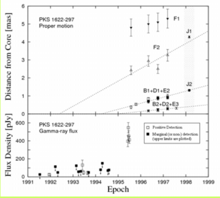
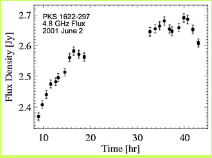


Figure 4: (Top) Distance of components from the core as a function of observed epoch. (Bottom) Gamma-ray light curve in picoJy observed by EGRET.

Results of ATCA Observations

- Flux variability feature
  - IDV was observed at both 4.8 and 8.6 GHz (see Fig. 5). This is the first detection of the IDV feature at 4.8 GHz toward PKS 1622-297.
  - Flux varied ~12% within eight hours at both 4.8 and 8.6 GHz on 2001 June 2-3.
  - Tendency of Annual modulation in the scintillation timescale (cf. Jauncey & Macquart 2001)



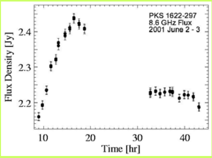
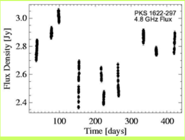


Figure 5: (Left and right) Total flux density at 4.8 GHz (left) and 8.6 GHz (right) on 2001 June 2 – 3, when the largest amplitude IDV was observed. Horizontal axis shows hours UT since 2001 June2, 00:00. (Bottom) Long-term flux variation at 4.8 GHz. Horizontal axis shows days since 2001 January 1.

- Variability brightness temperature
  - Assuming the intrinsic effect for observed IDV

$$\Rightarrow \quad T_{B,\mathrm{var}} \sim 1.5\times 10^{19}\left[\frac{S_\nu}{2.7\ \mathrm{Jy}}\right]\left[\frac{\lambda}{6.2\ \mathrm{cm}}\right]^2\left[\frac{d}{1092\ h^{-1}\ \mathrm{Mpc}}\right]^2\left[\frac{t_{\mathrm{obs}}}{1/3\ \mathrm{days}}\right]^{-2}\left[\frac{(1+z)}{1.815}\right]^{-2} \quad \mathrm{K}$$

An intrinsic origin for IDV is highly unlkely.



Discussion and Summary

- Relationship between gamma-ray emission and ejection of a new jet component

Component B2+D2+E3 and the large flare in 1995.48
- Difference of the viewing angle of B2+D2+E3 between dynamical model of the gamma-ray flare in 1995.48 (Romanova & Lovelace 1997) and that derived from the Doppler factor by the VSOP observation.
- Difference of the epoch between the gamma-ray flare and (extrapolated) ejection of component B2+D2+E3.

Component B2+D2+E3 would not be associated with the gamma-ray flare in 1995.48.

Component J1 and the local flare in 1991.95
- Coincidence between the ejection epoch of J1 and a local maximum in the gamma-ray emission at 1991.95

Suggesting a close relationship between ejection of a new jet component and gamma-ray emission

- Physical properties of PKS 1622-297
  - Having relatively low Doppler factor and large viewing angle compared to the other gamma-ray emitted AGNs
- Compactness of the inner region of PKS 1622-297
  - NE2001 Galactic electron density model (Cordes & Lazio 2002)
    - Transition frequency between weak and strong scattering of 31.7 GHz
    - Scattering disk sizes of 0.16 mas at 4.8 GHz and 0.04 mas at 8.6 GHz >> linear scale of ~10^{17} cm

Similar to the size of the gamma-ray emitting region (Sikora et al. 1997)

- Short timescale variability has been reported in 42% of EGRET-identified AGNs,
- Suggesting a higher incidence of IDV among gamma-ray sources (Wagner & Witzel 1995, Wajima et al. 2006).

References

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