SUB-MILLIARCSECOND RADIO STRUCTURE OF AO 0235+164 +

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AO 0235+164 is a very compact, flat-spectrum radio source. It is identified with a BL Lac object, and has optical absorption-line systems at z = 0.524 and z = 0.852. A complex set of HI absorption lines is seen at z = 0.524 (932 MHz), and several of these lines change significantly in depth over periods of less than a year. This is the only known case of variable extragalactic absorption lines. A faint nebulosity 2 arcsec south of AO 0235 + 164 has an emission-line redshift of z = 0.52 and may be an intervening galaxy. The radio spectrum of this source (between major outbursts) is remarkably flat, with the total flux density staying between about 1 and 3 Jy over a range of at least 1000 in frequency. Such a flat spectrum would lead one to expect a complex, wavelength-dependent structure consisting of several components with different self-absorption frequencies. However, the observed radio structure of 0235+164 is about as simple as one could imagine -- it is a nearly unresolved point source in VLBI experiments from 900 MHz to 22 GHz. Recent VLBI experiments at 6 and 13 cm have shown evidence for some elongation of the source in a generally NE-SW direction, but only at low contour levels (< 15% of the peak). The major portion of the flux density appears to come from a core which is unresolved in VLBI experiments over a range of ∿ 25 in frequency.

We observed 0235+164 in December 1982 at 22 GHz with a six-station VLBI array. The maximum baseline length was ∿ 600 million wavelengths, the minimum ∿ 40 million wavelengths. Our goal was to map the structure of this source with the highest possible resolution. The data were obtained with the Mk-III system in mode B, and correlated at Haystack. The Caltech VLBI programs were used to edit and calibrate the data, and to produce hybrid maps using both closure amplitudes and phases. These maps had dynamic ranges of about 50 to 1 near the central peak, and more than 100 to 1 several milliarcsecs away from the central peak. This is still a factor of 25 less than the dynamic range that could be achieved if the map noise level was set by the thermal noise from the receivers. The fact that the observed noise level is much higher than its theoretical value implies that there are uncorrected calibration errors in the data. These may be station-dependent errors which change more rapidly than the integration time used (60 seconds), or baseline-dependent errors. The usual

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self-calibration techniques can only adjust station gains once per integration interval, and thus can not correct for either type of potential error mentioned above.

The highest dynamic range map is one made with a 300 million wavelength taper in the U,V plane to search for extended, low surface brightness emission. Between 4 and 20 milliarcseconds from the core there are no peaks larger than ∿ 1 % of the central peak. However, the core is not completely unresolved. The untapered maps show a weak component approximately 1/2 milliarcsecond from the core component in position angle 210 degrees. It contains about 4 % of the flux of the core. The core itself appears to have some extended structure at low levels, but the resolution is not sufficient to determine the shape of this extension. The projected linear separation between the core and the component 1/2 milliarcsecond away is approximately 3 pc at z = 0.85, and the position angle is similar to that determined for larger-scale extensions at lower frequencies.

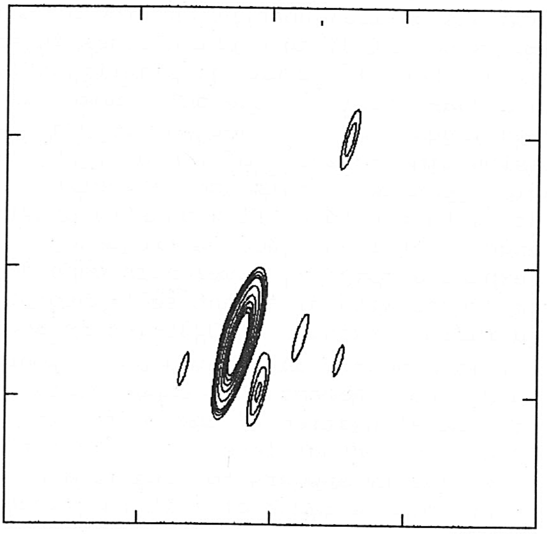

Figure 1. Hybrid map of AO 0235+164 at 1.3 cm. Contours are at 2, 3, 4, 5, 10, 20, 30, 40, and 50 percent of the peak, which equals 1.05 Jy per beam or a brightness temperature of 1.4 x 10**10 K. The clean beam is 1.00 by 0.18 milliarcsecs, with the major axis in position angle -15 degrees. The tick marks along the borders are 2 milliarcsecs apart.

The peak ∿ 3.5 milliarcseconds from the core in position angle -30 degrees may be real (it's about 5 sigma above the apparent noise level), but the most significant result is that this source continues to show a simple, nearly unresolved structure even at resolutions < 0.2 milliarcsec. As at lower frequencies, the secondary peaks are all very much weaker than the central peak.

AO 0235+164 has been detected in X-rays, and the observed X-ray flux can be combined with the measured radio parameters to determine a lower limit for the Doppler factor. This limit turns out to be > 3, which is independent evidence for bulk relativistic motion. This is consistent with the low-frequency variability which has been studied for many years and requires bulk relativistic motion to avoid severe Compton losses.

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