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Imaging the Absorbing Cloud at z = 0.88582 toward 1830–211

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Abstract. We summarize results of a detailed imaging program of the molecular absorbing cloud at z = 0.88582 toward the "Einstein ring" radio source PKS 1830–211.

Wiklind & Combes (1996) have discovered a strong molecular absorption line system toward the "Einstein ring" radio source 1830–211 at z = 0.88582 with $N(H_2) = 3\times10^{22}$ cm^{-2}. We have begun an extensive program of imaging the pc- and kpc-scale structures in this absorbing cloud in many molecular species and transitions in order to study the astrochemistry, physical conditions, structures, and dynamics of the dense ISM in this system. The VLA 47 GHz image and spectra of the redshifted HCN(1-0) absorption toward 1830–211 are shown in Fig. 1. We see strong absorption toward the SW component, with a peak opacity of 2.5 and FWHM = 25 km s^{-1}, and no absorption toward the NE component in this velocity range to an optical depth limit of 0.012 (3σ). The absorption along the two lines of sight is different, implying this must be a cosmologically intervening galaxy, and not the radio source redshift (Frye et al. 1997). We set a limit of 0.3 to the opacity toward the "tail" of the SW component, implying an upper limit to the cloud size of 600 h^{-1} pc. The VLBA image at 24 GHz and spectra of redshifted HC_3N(5–4) absorption are shown in Fig. 2. The continuum source shows a core-jet extending ≈ 2mas to the northwest. The spectra indicate an increase in absorbed flux density going to coarser resolution, suggesting a lower limit to the cloud size of 2.5 mas = 10 h^{-1} pc, although the HC_3N(3–2) absorption data indicate that there may be spatial sub-structure with velocity. The upper limit to the volume-averaged density is 1000 cm^{-3}, and the lower limit to the molecular mass is 2.6×10^4 $M_\odot$. These values are comparable to those found for giant molecular cloud complexes in our own galaxy (van Dishoeck et al. 1993). From VLA observations of HC_3N (3–2) and (5–4) we derive a temperature for the ambient radiation field of $4.5^{+1.5}_{-0.6}$ K, consistent with the temperature of the microwave background at z = 0.88582 ($T_{CMB}=2.73\times(1+z)=5.15$ K).

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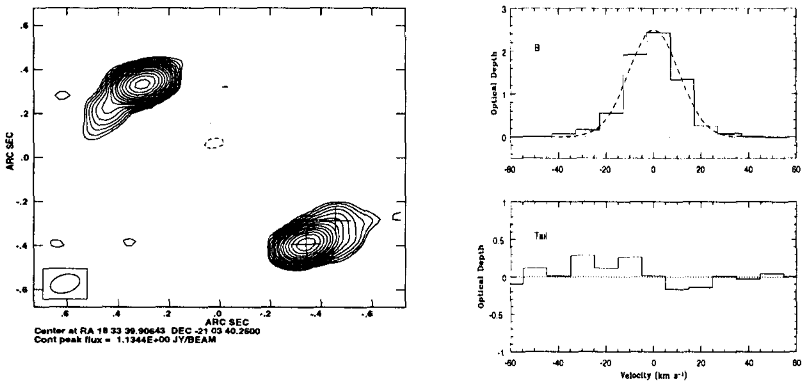

Figure 1. The figure on the left shows the continuum image of 1830–211 made with the VLA on January 25, 1997 at 47 GHz with a resolution of $\approx 0.1''$. The contour levels are a geometric progression in square root two, and the first level is 7.5 mJy/beam. The figure on the right shows redshifted HCN(1-0) absorption spectra toward the positions of the two crosses in the continuum image. Zero velocity corresponds to a heliocentric redshift of 0.88582 (central frequency = 46.999 GHz). The spectra have been converted to optical depth using the continuum surface brightness at each position. The upper spectrum is at the peak surface brightness of the SW radio component (B), with $F_\nu = 0.91$ Jy/beam. The dash line is a Gaussian fit to the data, with a peak opacity of 2.5 and FWHM = 25 km s^{-1}. The lower spectrum is at the tail of the SW component, where $F_\nu = 42$ mJy/beam. No absorption is seen toward the tail to an opacity limit of 0.3 (3σ), implying an upper limit to the absorbing cloud size of 150mas. No absorption is seen toward the NE radio component in this velocity range to an optical depth limit of 0.012.

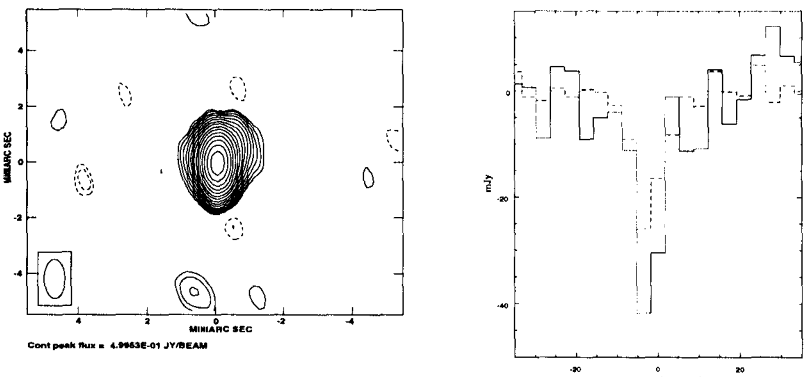

Figure 2. The figure on the left shows the continuum image of the SW component of 1830–211 at 24.1 GHz made with the VLBA on February 27, 1997 at $\approx$ 1mas resolution. Contouring is the same as Figure 1, with the first level = 3 mJy/beam. The figure on the right shows redshifted HC_3N(5–4) absorption spectra toward the SW component of 1830–211 (center frequency = 24.122 GHz). The dash line is a spectrum at the peak surface brightness at $\approx$ 1 mas resolution. The solid line is the same spectrum, but now at 2.5 mas resolution. The increase in the line flux density with coarser resolution suggests a lower limit to the cloud size of 2.5 mas.

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