Colloques internationaux du C.N.R.S.
N° 263 - L'ÉVOLUTION DES GALAXIES ET SES IMPLICATIONS COSMOLOGIQUES

21 CM OBSERVATIONS OF 3C 286

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Les observations VLB de la raie 21 cm en absorption décalée vers le rouge dans le QSO 3C 286 montre que le gaz s'étend dans une zone ≳0.01" avec une variation de vitesse de $3 kms^{-1}$. Ces observations rejettent l'hypothèse d'une enveloppe de gaz poussée par les photons émis, mais ne sont pas inconsistantes avec une absorption par une galaxie sur la ligne de visée.

21 cm absorption lines arise in gas different from material responsible for most optical absorption lines in QSOs. First the hydrogen must be mainly neutral. Second, the column density N(HI) must be large because the transition is magnetic dipole and stimulated emission is important. Third, the HI must be cold to reduce the latter effect. Hence a cloud of HI with $N(HI) \lesssim 10^{21}$ cm^{-2}, $T \lesssim 10^2 K$, and line width $\Delta v \lesssim 10$ Kms^{-1} will be optically thick to 21 cm radiation. We compare this to the ionized gas usually seen where $N(HI) < 10^{17}$ cm^{-2}, $T \sim 10^4 K$, and $\Delta v < 10^2$ Kms^{-1}. The HI systems are especially relevent to the origin of QSO absorption redshifts z_a and thus emission redshifts z_e because of their resemblence to gaseous disks in spiral galaxies.

The absorbing gas in the QSO 3C 286, $z_e = 0.85$, is an HI system as evidenced by a narrow, $\Delta v = 8.6$ Kms^{-1}, 21 cm absorption line at $z_a = 0.69$ (Brown & Roberts 1973). VLB observations of the continuum source (Purcell 1975) show it to consist of 3 components: a halo and two smaller components (fig. 1). If z_e is cosmological, the major axes of the halo and components A and B are 0.6, ≤ 0.16, and 0.25 Kpc respectively. VLB observations in the line may then distinguish an extended absorber from one confined to component A or B; i.e., an intervening galaxy from a cloud ejected with $u \approx 0.1c$. During July 21-25, 1975 J. J. Broderick, J. J. Condon, K. J. Johnston and the author made VLB observations of the 839 MHz feature using the 91 and 305m telescopes in Green Bank and Arecibo. The results of the experiment, described by Wolfe et. al. (1976), are that a very narrow, $\Delta v \approx 3$ Kms^{-1}, 10% dip in fringe amplitude is 2 Kms^{-1} redward of the pencil-beam dip, and 3 Kms^{-1} redward of the $\approx 8°$ phase shift between line and continuum.

To interpret these results (cf. Wolfe et. al. 1976) we refer to the fringe geometry of our baseline projected on Purcell's map of 3C 286 (fig. 1). The halo extends across a significant fraction of the 0.025"

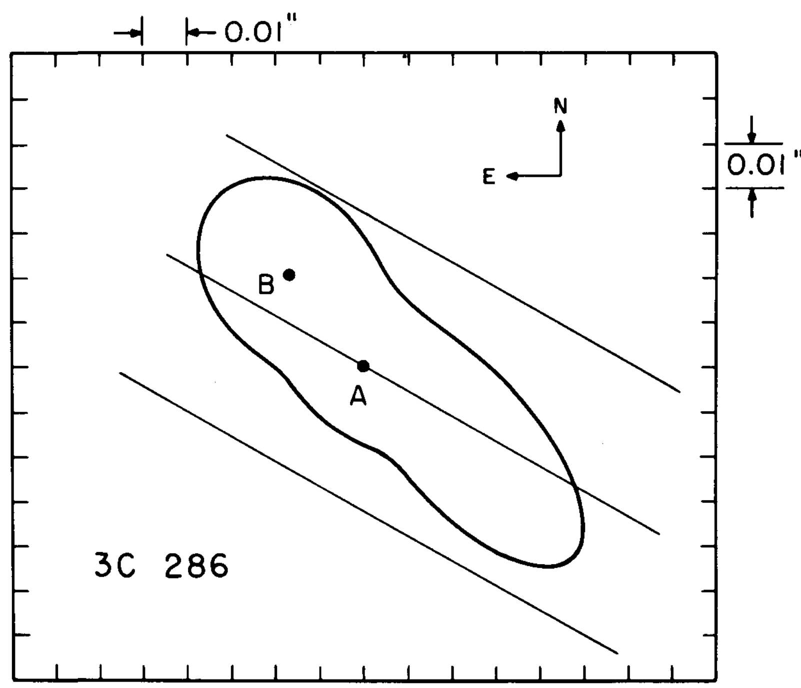

Fig. 1: Fringe maxima superposed on Purcell's (1976) 611 MHz map of 3C 286. A and B are brightness centroids of sources A and B.

separating two fringe maxima, and contributes little to the resultant fringe amplitude. Thus gas covering the halo could not be detected by our experiment, but would by the pencil beam. The VLB can detect gas in front of sources A and B which are only partially resolved with a fringe-amplitude ratio of 3:1. Fig. 1 shows that A and B are separated by a

https://doi.org/10.1017/S0252921100053896 Published online by Cambridge University Press

phase difference of $\sim 90°$. Thus the resultant fringe amplitude is the vector sum of 2 orthogonal components. Absorption of B causes the resultant to rotate without much change in amplitude, while absorption of A changes the resultant amplitude without much rotation. The VLB observations can then be explained if gas is in front of A and B with a velocity difference $v_A - v_B = +3$ Kms^{-1}. Alternative schemes invoking gas just in front of B, or a different VLB map fail unless gas extends across a significant fraction of a fringe separation. A decomposition of the amplitude and phase spectra along A and B shows that the line widths $\Delta v_A = 3.7$ and $\Delta v_B = 7.0$ Kms^{-1}. The sum of the flux changes, $\Delta A + \Delta B$, cannot account for the change in pencil-beam flux (cf. Davis 1975), indicating that gas extends across most of the halo.

The 3 Kms^{-1} velocity change across a scale of $\simeq$ 300 pc rules out radiative driving of intrinsic gas as the cause of the redshift difference $z_e - z_a$. An ejected shell must have a radius $R > 20$ Kpc to reduce velocity variations arising from curvature effects (fig. 2). This sets a small upper limit on the solid angle Ω subtended by the absorbing segment at the shell center. Thus a fixed segment of mass, hence solid angle, receives radiation for a time $t \sim R/u$ and absorbs a fraction $\Omega/4\pi$ of the total luminosity. The latter effect dominates since $\Omega \propto R^{-2}$, and the ratio of radiated to observed momentum $x = P_r/P_o \leq 7x\ 10^{-4}$. The conclusion that radiation emitted by 3C 286 cannot drive the absorbing gas to the required velocity is a general one and holds under variations in model parameters and QSO-distance D. Since $x \propto D$, the momentum defecit worsens if the QSO is local, or if the adopted cosmological parameters $q_o > 0$ and $H_o > 50$ Kms^{-1} Mpc^{-1}. The ejection hypothesis cannot be ruled out altogether since cosmic rays can supply the momentum needed by the gas when particle energies 10^{62} ergs sr^{-1} (cosmological D) or $10^2 - 10^5$ times the equipartition energy of the radio source (local D) are provided.

If the absorber is the HI disk of an intervening galaxy, turbulent motions must dominate systematic rotation as the line-broadening agent. The turbulence level must be less than in our own Galaxy since individual motions of the many interstellar clouds in the ~ 1 Kpc^2 subtended at the

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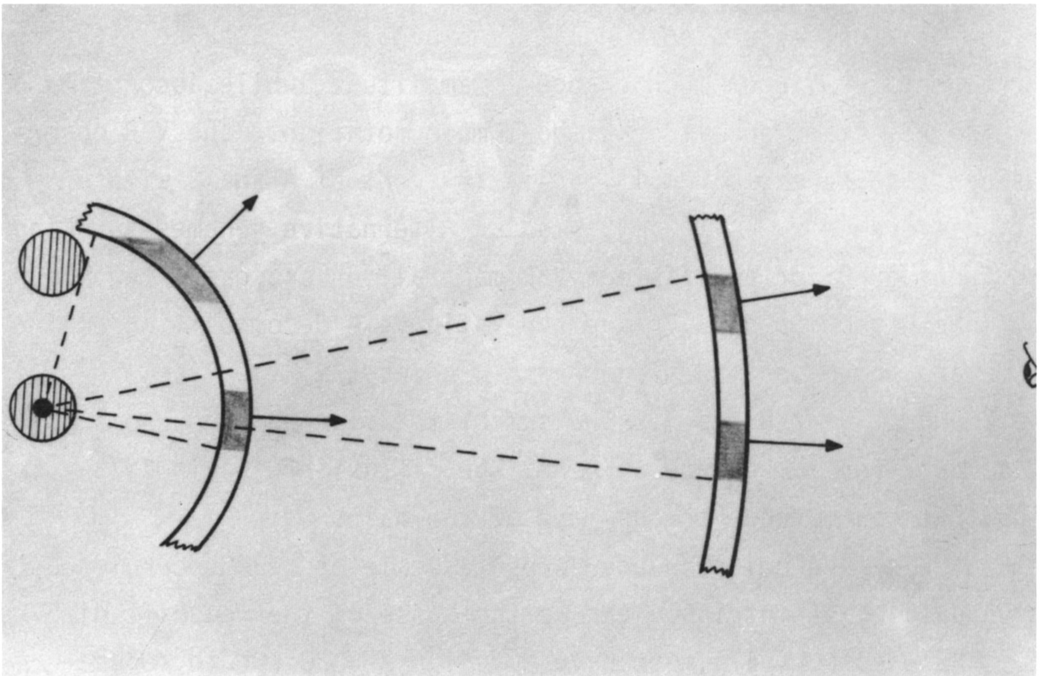

Fig. 2: Geometry and kinematics of ejected shells with small and large radii detected in absorption against components A and B.

galaxy by the radio source would result in a line 15 rather than 8.6 Kms^{-1}. wide. The area subtended by component B, though smaller, would still include hundreds of clouds, which is consistent with the similarity between the 7.0 and 8.6 Kms^{-1} widths of the two profiles. The area subtended by A should also include many clouds. But the 3.7 Kms^{-1} line width resembles that due to a single cloud. Two possibilities are 1) that a large-scale, low-velocity-dispersion sheet of HI similar to interstellar configurations observed by Heiles (1974) is in front of A; or 2) that most of the flux from A is emitted by an unresolved core which subtends an area small enough to include $\sim$ 1 cloud. In any case the observations are consistent with the intervening-galaxy hypothesis.

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DISCUSSION

G. DE VAUCOULEURS: What is the evidence against absorption by an HI cloud, rather than the disk of a galaxy?

A.M. WOLFE: The 21 cm data alone cannot distinguish between a primordial HI cloud and a galactic disk. However, Spinrad's recent detection of Mg and Fe at the same absorption redshift as the 21 cm line in 3C 286, and at approximately the solar abundance argues against a primordial cloud.

J. TERRELL: There have been reports in the press that your results have finally proved that quasars are at cosmological distance. Is this your view?

A.M. WOLFE: The term "finally proved" is of course too strong. However, these observations place very severe constraints on any ejection scheme. I think the burden of proof now lies with originators of local theories, like yourself, to come up with a plausible mechanism to explain these observations.

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