Observations of the cosmic background radiation near the double quasar 1146+111B,C

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Paczynski[1] and Turner *et al.*[2] have suggested that the extraordinary double quasar 1146+111B,C found by Hazard *et al.*[3] is a possible gravitational lens. The hypothetic lensing object is unknown. If the lensing object is a cluster of galaxies[4] or a cosmic string[5,6], it may cause observable effects in the cosmic background radiation. At millimetre wavelengths, a cluster would be expected to cause a reduction in the temperature of the background in the vicinity of the cluster as the result of the Zeldovich–Sunyaev effect. The area of sky on one side of a cosmic string would have a different radiation temperature from that on the other side. If either of these expected signatures were seen in the cosmic background, it would be strong evidence in favour of that hypothesis. We have searched for microwave background inhomogeneities near 1146+111B,C. An east–west strip of sky, 16 arc min long and centred on the point between the quasars, was observed with a beam of diameter 105 arc s at 3 mm wavelength. Our observations show only noise with an r.m.s. noise level of 0.0010 K. These observations set limits on the properties of the lensing object if it is a cosmic string or a cluster of galaxies, and we do not confirm either hypothesis.

Observations were made for 4-h periods on each of seven nights in March and April 1986, using the 7-m-diameter antenna at AT&T Bell Laboratories, Crawford Hill. At 100 GHz, this antenna has a beam efficiency of 0.92 and a beam size of 105 arc s (full width at half maximum). The receiver is a superconductor-insulator-superconductor (SIS) mixer followed by an FET (field-effect transistor) amplifier with 512 MHz bandwidth. Double-sideband receiver temperatures were typically 90 K, and the total system temperature including atmospheric corrections was 180–300 K. The receiver gain and noise were measured every half hour by chopping between a liquid-nitrogen-cooled absorber and a room-temperature absorber. The sky temperature was measured by chopping between the sky and the liquid nitrogen absorber, which allows a calculation of the atmospheric opacity.

The observing method was a beam-switched drift scan, as described by Radford *et al.*[7]. As the source moved across the sky, the antenna was driven to a position ahead of the source and then held stationary with respect to the Earth. The observed strip would then drift through the beam. To eliminate the effect of gain fluctuations, the receiver was chopped at a frequency of 15 Hz between the primary beam and a reference position at 30 arc min greater azimuth, so that the observed value of a point on the strip is the difference in antenna temperature between that point and the reference position. The time series that resulted from each drift scan was binned at intervals corresponding to 1 arc min on the sky, slightly larger than half a beam-width. Many drift scans were averaged to yield the plot in Fig. 1. The reference positions changed as the source moved across the sky, because of field rotation. The chopping was done with a rotating blade at the Cassegrain focus[8]. Before each night's observations the system was checked by drift-scan observations of calibration sources with known millimetre-wave fluxes.

The results are shown in Fig. 1. Here, all the drift-scans have been averaged. None of the data have been discarded. Figure 1 shows corrected antenna temperature as a function of position along the strip. The zero-point of the temperature scale has been arbitrarily set so that the average value along the strip is zero;

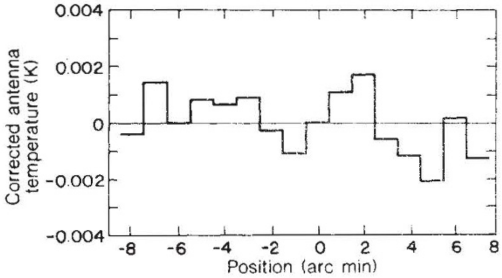

Fig. 1 Corrected antenna temperature at 100 GHz as a function of position along a constant declination strip passing between the quasars 1146+111B,C. The 0 arc min position is $\alpha_{1950}=11$ h 46 min 06 s, $\delta_{1950}=11° 05' 28''$. West is to the left, east to the right.

therefore, the data do not show possible differences between the strip and the reference positions. However, a step or a slope in the brightness as a function of position along the strip would appear in the plot.

These data seem to be random. The r.m.s. noise level is 0.0010 K. If the lensing object is an isothermal cluster there is a predicted[4] Zeldovich-Sunyaev dip of $\Delta T \simeq -0.003$ K$\beta f h^{-2}$ centred on the 0 arc min position in Fig. 1, where β is a geometrical factor of order unity, f is a factor of order unity that measures the fraction of the mass in the form of ionized gas ($f \equiv M_{\rm ionized}/[0.03\, M_{\rm virial}]$; for the Coma cluster $f=1$) and $h \equiv H_0/100$ km s^{-1} Mpc^{-1}, where H_0 is the Hubble constant. If the lensing object is a stright cosmic string there is a predicted[6] step of $\Delta T \simeq 0.002$ K v_s/c of either sign where v_s is the velocity of the presumably relativistic string perpendicular to its length and to our line of sight. The step could be located anywhere from position −3 to +3 arc min, because the string might lie anywhere between the quasars. It would be broadened by ~2 beam-widths because the position angle of the string is most likely to be 63°, that is, perpendicular to the line between the quasars. Both a cluster and a string would be expected to affect several of the independently measured points on our spatial strip, so the statistical significance of our non-detection is greater than the noise in any single point. The data are consistent with a limit of $\beta f h^{-2} \leqslant 0.3$ for the cluster. The hypothetical cluster would then have to be relatively poor in ionized gas: the factor $M_{\rm ionized}/M_{\rm virial}$ would be one third of the Coma cluster value. The data are also consistent with a limit of $v_s \leqslant 0.5\,c$ (where c is the speed of light) for the case of a string. A string would be expected[5] to have $v_s \simeq 0.5$ c, so our measurment does not rule out the string hypothesis, but this measurement constrains the properties of the string. For example, the apparent projected angle, χ, between the string and the normal to the line between the quasars is given by [6] $\tan(\chi)=(v_s/c)\tan(\alpha)$, where α is the angle between the string and the plane of the sky.

The data are, of course, also consistent with the negative hypothesis that B and C are two different quasars that coincidentally have very similar spectra, and that there is no lens at all. At the 3σ level of statistical significance, there is no effect on scales of $\geqslant 105$ arc s at a level of 10^{-3} of the cosmic background radiation.

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