first two of these explanations, since both the primary sequence and the transient expression of the mutant gene are the same as for the normal gene. Our sequence data, however, do not exclude changes in the region upstream from −100, which might affect the expression of the gene *in vivo*[26,27,33]. To this we can add that the presence of translocated sequences *per se* next to the 5′ regions of the β-globin gene does not have a negative effect on the expression of the gene: the *Kpn* subclone which contains 2.5 kb of sequences from the translocated DNA is accurately and efficiently transcribed in our experimental system, although we cannot exclude that translocated sequences even further upstream might have such an effect.

The third explanation which postulates the lack of a *trans*-acting component originating in the deleted region of the chromosome in the $\gamma\beta$-thalassaemia, leaving both β-genes active, but at a reduced efficiency, was described as unlikely[11], but could not be excluded. This explanation predicts that both the β-globin genes of the patient would be in a transcriptionally 'active' state. Our data clearly contradict this prediction, since they show the normal locus to be in an 'active' state, and the affected locus to be in an 'inactive' state.

This observation clearly favours the fourth explanation which postulates a *cis* influence of sequences far from the β-globin gene. Whether this *cis* effect is exerted by the removal of regulating sequences, or the addition of actively suppressing sequences upstream from the β-globin gene is at present unclear. Any of these possibilities could block the normal progression of globin gene expression during normal erythropoiesis[28], or alter the ability of this chromosomal region to be expressed, for example, by the use of a different replication origin[29]. Either way, in both cases, the net result is a position effect similar to those found in *Drosophila*.

The transposed DNA in $\gamma\beta$-thalassaemia is normally found in an area of the chromatin which is DNase I insensitive and hypermethylated. Consequently, after the deletion the affected β-globin gene is present in a chromatin domain that is not expressed in erythroid tissue, resulting in the silencing of the β-globin gene.

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LETTERS TO NATURE

Can pregalactic stars or black holes generate an IR background?

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Matsumoto *et al.* report[1] that they have detected an IR background in the waveband 2–5 μm which has a density $\Omega_R \sim 10^{-4} h^{-2}$ in units of the critical density ($\rho_{crit} = 5\times10^{-30} h^2$ g cm^{-3} with $H_0 = 50h$ km s^{-1} Mpc^{-1}) and an approximately black-body spectrum with a temperature of about 1,500 K. They claim that the intensity is too high to be explained by zodiacal light, interplanetary dust, low mass halo stars or galactic emission, and suggest that it is derived from a generation of pregalactic (population III) stars. We argue here that this is possible only if the stars began forming at a redshift exceeding 40 with a density parameter $\Omega_* \sim 1$ and a mass in the range 10^2–10^5 M$_\odot$. With such a high density, they could avoid over-enriching the background medium with heavy elements only if they collapsed to black holes after their nuclear burning phase[2]. These holes may also have contributed to the IR background, provided they formed optically thick accretion disks. However, we argue that holes could generate the entire background only if they have a density parameter $\Omega_B \sim 0.1$ and a mass in the range 10^6–$10^8 M_\odot$, in which case they would be too large to have stellar precursors.

We first assume that the stars are all VMOs with a mass M exceeding 200 M$_\odot$, in order to collapse to black holes[3,4] and thereby avoid over-enrichment; in this case, their luminosity is $L = 1.3\times10^{38}\,(M/M_\odot)$ erg s^{-1} and their surface temperature is $T_s \simeq 10^5$ K. If they all form at the same redshift z_*, their radiation will also be generated at that epoch providing their main-sequence time ($t_{MS} \simeq 2\times10^6$ yr) is less than the expansion time, which requires $z_* < 300h^{-2/3}$. This means that the background radiation from the stars should just have a redshifted black-body spectrum with present temperature $T_{bb}^{obs} \simeq 10^5\,(1+z_*)^{-1}$K, providing there is no absorption by grains or neutral hydrogen. The integrated energy density of the background is

$$\Omega_R = 0.004\left(\frac{f_b X_0}{0.6}\right)\Omega_*(1+z_*)^{-1} \qquad (1)$$

in units of the critical density, where the coefficient is the product of the efficiency of energy release in burning hydrogen to helium (0.007) and the fraction f_b of the hydrogen mass burnt to helium, and X_0 is the initial hydrogen abundance ($1 \geq X_0 \geq 0.75$); $f_b X_0 \simeq 0.6$ for a VMO with $X_0 = 0.75$ (ref. 3). We will describe the spectrum in terms of the density parameter $\Omega_R(\nu) \equiv 4\pi w i(\nu)/\rho_{crit} c^3$ (where $i(\nu)$ is the intensity per unit frequency interval) because this best emphasizes the energetic requirements of our model. The predicted spectrum is then

$$\Omega_R = 6.5\times10^{-4}\left(\frac{f_b X_0}{0.6}\right)\left(\frac{\Omega_*}{1+z_*}\right)\left(\frac{x^4}{e^x-1}\right) \qquad (2)$$

where $x \equiv \hbar\nu(1+z_*)/kT_s$; this peaks at $\nu = 8.1\times10^{15}(1+z)^{-1}$ Hz, corresponding to $\lambda = 3.7\times10^{-6}(1+z_*)$ cm.

Equation (2) is compared with the data in Fig. 1. If we assume $X_0 = 0.75$, a representative fit is shown by curve a in Fig. 1 and

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requires $z_* \simeq 100$ and $\Omega_* \simeq 2.5h^{-2}$. This fit does not pass through the 2-μm point; if one includes that point but neglects the 5-μm point (which is the most dubious since it could be contaminated by interplanetary dust emission), the best fit is shown by curve *b* and requires $z_* \simeq 75$ and $\Omega_* \simeq 1.6h^{-2}$. More generally, one might demand that the spectrum should peak between 2 and 5 μm, the range spanned by the data; the first limit is also necessary if the spectrum is to fall sufficiently to go below the optical limit[5] at 0.5 μm. (The limit on pregalactic stars imposed by optical observations has been discussed elsewhere[6,7].) This corresponds to redshifts $50 < z_* < 140$, which implies that the stars certainly need to be pregalactic, the redshift of galaxy formation (z_g) usually being assumed to be about 10. The value of Ω_* required is necessarily close to 1. This may not conflict with the upper limit permitted by measurements of the cosmological deceleration parameter[8], and it would certainly suffice to explain the dark matter problem[9]. However, it would be too large to be consistent with the observed deuterium abundance if this results from cosmological nucleosynthesis[33].

If M is allowed to fall below 200 $M_\odot$ (despite the enrichment constraints), the value required for $z_* (\propto T_s)$ decreases; the value required for $\Omega_* (\propto T_s f_b^{-1})$ first increases slightly[2] (as $M^{-0.2}$) and then decreases[7] when M falls below 20 $M_\odot$. One can thus ease the constraints on Ω_* by using sufficiently small stars; furthermore, stars smaller than 4 $M_\odot$ might avoid returning any heavy elements. However, a high density of stars between 0.3 and 4 $M_\odot$ would produce a spectrum which contravenes the optical limits[6], so this possibility does not seem very plausible. Nor does it help if the stars form over a range of redshifts or have a mass small enough that they burn out after z_*: this could extend the spectrum somewhat (including all the data points) but it does not obviate the energetic problem.

In some circumstances one might expect the spectrum to be cut off at wavelengths below the redshifted Lyman limit, $\lambda_i = 0.09(1+z_*)$ μm, with corresponding Lyman-α emission at $\lambda_\alpha = 0.12(1+z_*)$ μm, because of absorption by neutral hydrogen. This will not be possible if the neutral fraction is below[2]

$$1 - x \approx 10^{-5}\Omega_g^{-1}(1+z_*)^{-3/2}\Omega^{1/2}h^{-1} \tag{3}$$

(where Ω_g is the gas density and $\Omega \geq \Omega_g$ is the total density) and sufficient ionization will be ensured by the stars themselves unless the gas clumpiness exceeds[2]

$$\delta \simeq 5\times 10^5 \Omega_* \Omega_g^{-2}(1+z_*)^{-3/2}\Omega^{1/2}h^{-1} \tag{4}$$

However, such a large clumpiness is not inconceivable: it could be ensured, for example, if most of the gas goes into bound clouds at decoupling or if each star is surrounded by a dense mass-loss atmosphere.

If the spectrum is cut off at λ_i, it is crucial whether the stars form over an extended redshift range. If they do not, and if $t_{MS} \ll t_*$, then the only detectable radiation will be the fraction f_P of the continuum below the Lyman limit ($f_p \simeq 0.11$ for VMOs), although one of the data points may be boosted by Lyman-α emission. In this case, the observations require $0.5\ \mu m < \lambda_i < 2\ \mu m$, corresponding to $21 > z_* > 5$, but we still need a large value for Ω_*. Also, as shown by curve *c* in Fig. 1, which corresponds to $z_* \simeq 17$ and $\Omega_* \simeq 1.2h^{-2}$, the spectrum is too steep to explain all the data. On the other hand, if the stars form over an extended range of redshifts (z_1 to z_2), the Lyman-α density would dominate the background for $0.12(1+z_1)\ \mu m > \lambda > 0.12(1+z_2)\ \mu m$. If we assume that one Lyman-α photon is emitted for each ionizing photon absorbed, one can explain the observations providing $z_1 > 41$ and $z_2 < 11$. If the stars are assumed to form at a rate $\phi(z)$ in units of the critical density per redshift interval, then the Lyman-α density over the indicated wave band is

$$\Omega_\alpha(\nu) = (0.004)\phi(z = \nu_\alpha/\nu - 1)\left(\frac{X_0 f_B}{0.6}\right) \times \left[\int_{x_i}^{\infty} \frac{x^2 x_\alpha\, dx}{e^x - 1} \Big/ \int_0^{\infty} \frac{x^3\, dx}{e^x - 1}\right] = 1.2\times 10^{-3}\phi(z(\nu)) \tag{5}$$

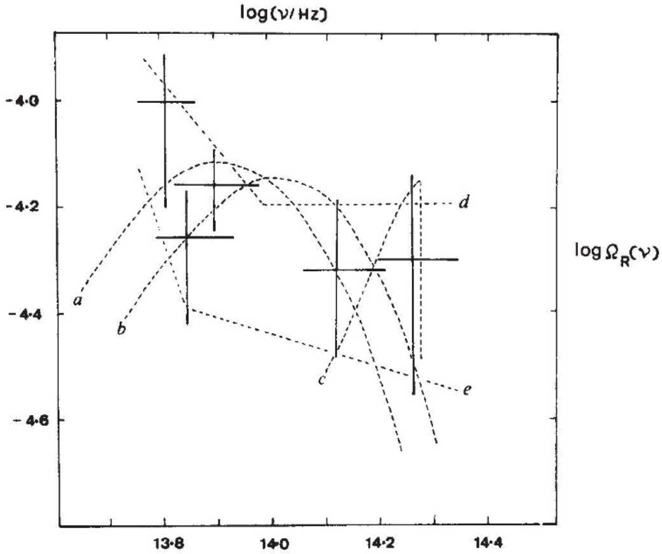

Fig. 1 Comparison of the observed IR data points, represented in terms of the spectral density parameter $\Omega_R(\nu)$ as defined in the text, with various predicted spectra. Curves *a* and *b* are the best-fit black-body spectra if one neglects the 2- and 5-μm points, respectively. These curves could represent the background generated by pregalactic starlight provided the stars form and burn at a single redshift and provided there is no absorption above the Lyman frequency. If there is a Lyman cut-off, the spectrum would be like curve *c* and would be too steep to explain all the data. If the stars form over a range of redshifts, the spectra would be more extended and could conceivably fit all the data points. This applies even if there is a Lyman cut off, since the Lyman-α line would then be spread over a wide waveband, as shown by curves *d* and *e*.

By choosing $\phi(z)$ carefully, one could in principle fit any set of data points. Curves *d* and *e* in Fig. 1 correspond to the maximum and minimum energetic requirements, the associated form for $\phi(z)$ being entirely *ad hoc*. If one allows for the extra continuum contribution, these curves require a total star density $\Omega_* \simeq 1.7h^{-2}$ and $0.8h^{-2}$, respectively. Thus, providing the gas in the Universe is sufficiently clumped, Ω_* can be reduced somewhat, although it still exceeds the deuterium limit. Also, since $z_1 > 41$, star formation must still begin in the pregalactic era.

Various complications could modify the predicted spectra in Fig. 1. For example, some of the short-wavelength radiation could be absorbed by grains[10–17]; energetic requirements would then demand an even larger value for Ω_* than indicated above. Another possibility would be to assume that the stars have an extended rather than discrete mass spectrum. However, this would only be relevant if the spectrum extended below $10^2\ M_\odot$ since the form of $\Omega_R(\nu)$ is independent of M for VMOs. Note also that objects larger than $10^5\ M_\odot$ do not produce any appreciable starlight since such SMOs collapse due to relativistic instabilities before burning their nuclear fuel if they have no initial heavy element content[18].

The black-hole remnants of pregalactic stars, as well as black holes with no stellar precursors, would inevitably accrete the background matter[19,20]. If the holes accrete at the Bondi rate[21], and radiate with an efficiency ε, each one should have a luminosity

$$L = 1.1\times 10^{32}\varepsilon M^2 n_g T_4^{-3/2} \quad \text{erg s}^{-1} \tag{6}$$

provided this is less than the Eddington limit ($L_{ED} = 1.3\times 10^{38} M$ erg s^{-1}). Here M is the mass of the hole (in $M_\odot$) and n_g and T_4 are the particle density (in cm^{-3}) and temperature (in 10^4K) at the accretion radius ($R_A = 8\times 10^{13} M T_4^{-1}$ cm). R_A is always less than the mean hole separation in our scenario. Since the background matter is heated by the radiation from accretion, the evolution of n_g and T may be very complicated (especially during the period when the holes are surrounded by individual H II regions[19]). However, once the Universe is ionized, we always have $n_g = 3\times 10^{-6}\Omega_g h^2(1+z)^3$ cm^{-3} on average.

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The effect of the holes is crucially dependent on their radiation spectrum. If we take the standard disk accretion model, calculations[22] indicate that a 'soft' spectrum of black-body form is realized if the accretion rate is less than $\dot{M}_{bb} \simeq 1\times10^{16}M^{7/8}$g s^{-1}. This is equivalent to $L<0.02M_6^{-1/8}L_{ED}\varepsilon$, where $M_6 \equiv M/10^6 M_\odot$. In this case, the black-body temperature is

$$T_{bb}=\left(\frac{L}{4\pi R_i^2 a}\right)^{1/4}=2.1\times10^4\varepsilon^{1/4}\Omega_g^{1/4}T_4^{-3/8}(1+z)^{3/4}h^{1/2}\quad \text{K} \tag{7}$$

where R_i is taken as $10GM/c^2$, corresponding to the inner edge of the accretion disk. We note that T_{bb} is independent of M and the spectral peak is on the low energy side of the Lyman cut-off providing $1+z<17(\varepsilon\Omega_g h^2/10^{-2})^{-1/3}T_4^{1/2}$. In this case, in trying to fit the data, the issue of whether condition (3) is satisfied is not crucial. Of course, the spectrum will not be exactly black body: it will be smeared out because of the range in M and z, and even the spectrum from an individual hole will not be perfect black body because there will be contributions from cooler points of the accretion disk with $R \gg R_i$.

The present energy density and temperature of the black-body radiation generated by the holes at redshift z are respectively

$$\Omega_{IR}=\frac{Ltn_B}{(1+z)\rho_{crit}c^2}$$
$$=8\times10^{-5}\,\varepsilon M_6\Omega_B\Omega_g\Omega^{-1/2}(1+z)^{1/2}T_4^{-3/2}h \tag{8}$$

and

$$T_{bb}^{obs}=2.1\times10^4\{\varepsilon\Omega_g h^2(1+z)^{-1}\}^{1/4}T_4^{-3/8}\quad \text{K} \tag{9}$$

Here $t=4\times10^{17}\Omega^{-1/2}h^{-1}(1+z)^{-3/2}$s is the age of the Universe at redshift z, and $n_B=2.5\times10^{-69}\Omega_B M_6^{-1}h^2$ cm^{-3} is the present number density of the holes. The nice point is that T_{bb}^{obs} is in the range 10^3–10^4 K for reasonable values of ε, Ω_g and T_4, and depends on z only weakly.

We now estimate the epoch z_{bb} after which the generated spectrum is approximately black body. This requires that the accretion rate be less than $\dot{M}_{bb}$, implying

$$1+z_{bb}=17\,M_6^{-3/8}\Omega_g^{-1/3}h^{-2/3}T_4^{1/2} \tag{10}$$

On the other hand, the matter temperature T_4 is determined by the balance between heating and cooling. The heating will be due to photoionizations from the fraction $(1-f_p)$ of the total energy flux above the Lyman limit, while the cooling will be primarily due to Compton scattering of electrons off the microwave background and line emission. For the range of values of f_p anticipated, one expects T to be boosted to a value in the range 10^4–10^5 K, with the Universe being reionized, but not appreciably higher. Since T_4 remains nearly constant, equation (8) implies that the main contribution to the background radiation is derived from z_{bb}. The contribution from $z<z_{bb}$ merely extends the spectrum to slightly higher frequencies. Before z_{bb}, the same holes might have generated X rays with a luminosity close to L_{ED}. In this case, a larger fraction of their energy would have gone into heating the background because of their Compton heating effect[19] and T could be boosted well above 10^4K in some period.

Putting $z=z_{bb}$ in equation (8), we estimate the hole mass required as

$$M=4\times10^6\left(\frac{\varepsilon}{0.1}\right)^{-1.2}\Omega_B^{-1.2}\Omega^{0.6}\Omega_g^{-1.0}h^{-3.2}T_4^{1.5}$$
$$\times\left(\frac{\Omega_{IR}}{10^{-4}h^{-2}}\right)^{1.2}M_\odot \tag{11}$$

Thus (for given values of ε, Ω and Ω_g) M, Ω_B and z_{bb} are determined once any one of them is specified. We note that the spectrum goes soft before galaxy formation provided

$$M<3\times10^7\left(\frac{\Omega_g}{0.1}\right)^{-0.9}\left(\frac{1+z_g}{10}\right)^{-2.7}h^{-1.8}T_4^{1.3}M_\odot \tag{12}$$

which implies

$$\Omega_B>0.2\left(\frac{\varepsilon}{0.1}\right)^{-1}\left(\frac{\Omega_g}{0.1}\right)^{-0.1}\left(\frac{1+z_g}{10}\right)^{2.2}T_4^{0.2}\Omega^{0.5}h^{-1.2}$$
$$\times\left(\frac{\Omega_{IR}}{10^{-4}h^{-2}}\right) \tag{13}$$

On the other hand, we require M to exceed the value given by equation (11) with $\Omega_B=1$. Thus, the mass and density of the holes in this scenario can be specified fairly precisely: M has to be roughly 10^6–$10^8\,M_\odot$, corresponding to precursors in the SMO range, and Ω_B has to exceed about 0.1, which would be sufficient to provide the dark matter[9]. Equations (10) and (11) also imply that the radiation comes from a relatively recent epoch, even though the holes themselves may form much earlier. If $z=z_{bb}$ is placed in equation (9), a temperature

$$T_{bb}^{obs}=4\times10^3\,M_6^{0.1}\left(\frac{\varepsilon}{0.1}\right)^{1/4}\left(\frac{\Omega_g}{0.1}\right)^{1/3}T_4^{-1/2}h^{2/3}\quad \text{K} \tag{14}$$

is obtained. Note that the temperature would be smaller if the holes had thick accretion disks, thus increasing the value of R_i in equation (7). Since both the parameters T_4 and R_i are uncertain, one cannot predict T_{bb}^{obs} very precisely.

It is interesting to consider what happens if M is outside the required range. The pregalactic Universe has two spectral windows where it is optically thin[23]: one in the X-ray band and one below the Lyman limit. If M exceeds the value specified by equation (12), the holes will never have a soft spectrum in the pregalactic era and will therefore contribute only to the X-ray window. For smaller masses, one can envisage the holes contributing to both windows successively, although their contribution to the IR background will be too small to explain the data if M is less than the value specified by equation (11) with $\Omega_B=1$. It is therefore natural to suggest that the X-ray background was generated by very massive holes[24–27], while the IR background was generated by somewhat less massive ones.

The black holes would also accrete after galaxy formation but their luminosity would then depend on their environment[28]. If they resided in galactic halos or clusters, their luminosity would be too low to explain the IR background, although holes traversing the disk might present detectable individual IR sources[29]. Holes in the cosmological background could not contribute appreciably to the IR background because, even if there is a large gas density there, its temperature[30] must exceed 10^6K, suppressing the luminosity by at least $\sim10^3$. Giant holes in galactic nuclei might, however, generate an appreciable IR background[31].

In conclusion, either stars or black holes could explain the IR background. If stars are responsible, they almost certainly have to be pregalactic VMOs with a density close to critical. If holes are responsible, they would have to be SMOs and their density and the redshift from which their radiation is derived could be somewhat smaller. Various observational features may decide which explanation is better. In particular, the detection of any anisotopy on the scale of galaxies and clusters ($\sim1'$) or the identification of a Lyman-α line would be important. Even if the claim of Matsumoto *et al.* is not confirmed, their results nevertheless confirm previous indications[32] that Ω_{IR} cannot exceed about 10^{-4}. Thus Fig. 1 and equation (11) necessarily impose interesting constraints on Ω_* and Ω_B.

Another important issue is whether the stars or black holes could contribute to the 3 K background[10–17]. Since one of the reasons for suggesting this is that one would expect these objects to generate $\Omega_R\sim10^{-4}$ if they provide the dark matter[2], the discovery of another waveband with this density may actually make this less plausible. Nevertheless, it is interesting to enquire whether pregalactic objects could generate two backgrounds with $\Omega_R\sim10^{-4}$. Objects larger than $10^5\,M_\odot$ could generate radiation efficiently only in their black-hole stage; they might generate the 3 K background at $z>10^3$, if one invokes free–free thermalization[13], as well as the X-ray background before z_{bb}

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or the IR background after z_{bb}. Objects smaller than $10^5 M_\odot$ could contribute to the 3 K background during their nuclear-burning stage provided their light can be thermalized by grains[10–17]. They might conceivably generate both the 3 K and IR backgrounds sequentially if the grains thermalize only at sufficiently large redshifts[27]. However, the accretion-generated radiation from their remnants would be too small to explain either background.

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A new limit on the nature of the galactic missing mass

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It has been widely accepted that large amounts of 'missing' mass must be present in spiral galaxies to explain both the small-scale and large-scale kinematic observations[1]. The small-scale data (velocity dispersions in the solar vicinity) refer to the volume within a few hundred parsecs of the Sun, and indicate that 25–50% of the gravitating mass has no detected luminous counterpart[2–4]. The large-scale data (velocity dispersions and rotation curves) show that this non-luminous component becomes increasingly important with increasing galactocentric distance, and is the dominant mass in the outer regions of galaxies, and in total. It is usually assumed that both the local and global missing mass are the same substance although no plausible candidate for this substance is known. The most widely assumed, and most conservative, candidate is a large population of very low-luminosity M dwarfs. These stars are attractive, both because they exist in large numbers, and because their mass (M) to light (L) ratios are similar to those needed to explain flat rotation curves ($M/L \sim 100$–$1{,}000$). Finally, they are of very low intrinsic luminosity, and it is therefore observationally very difficult to determine their true space density from blue or visual surveys. We present here new observational results which show that low-luminosity M dwarfs are unlikely to provide the large-scale missing mass, and cannot provide the small-scale missing mass.

Low-mass luminous stars are very red, and may be readily detected and studied using current red-sensitive photographic emulsions and charged coupled device (CCD) detectors. We are therefore carrying out a survey using red-sensitive plates from the UK Schmidt Telescope in Australia which are scanned with the COSMOS machine at the Royal Observatory of Edinburgh to discover complete samples of red dwarfs. The stars are then studied individually in the near IR and/or spectroscopically to determine their space density and physical properties. We have presented elsewhere the first results (refs 5–7 and work in preparation), which are a survey of ~18 square degrees near the south galactic pole to $I = 17$. This is the first volume-complete determination of the local space density of low-mass stars which is complete for all stars sufficiently massive to burn hydrogen, and shows that M dwarfs do not provide the solar neighbourhood missing mass. However, very few stars with $M_v \gtrsim +15$, mass $\leq 0.1\ M_\odot$, were included in that survey. The statistical significance of our mass limit on the lowest mass luminous stars was therefore capable of improvement.

We have now extended the survey to constrain the M dwarf contribution to the larger-scale missing mass. To do this we have derived a sample of all those stars which have $I \leq 18.25$ and $B_J \gtrsim 22$, where B_J refers to the IIIa-J+GG395 photographic passband, in a total of 50 square degrees distributed over several fields. (A discussion of the data for the other stars in these fields will be presented elsewhere.) This sample has a surface density very near 1.0 per square degree, and is restricted, allowing for the colour term in the B_J system, to stars with $M_v \gtrsim +15$ within about 200 pc of the Sun. To determine the absolute magnitudes of the sample, and hence the space density and total mass density, we observed a random subsample of these stars (complete observations were prevented by poor weather) with the Cerro Tololo Interamerican Observatory (CTIO) 4-m telescope, RC spectrograph and CCD detector in July 1983. Spectra with signal-to-noise ratio ~100 were obtained in ~30 min per star, and are shown in Fig. 1. Also shown are spectra obtained at the same time of several low-luminosity stars with reliably determined absolute magnitudes. Comparison of the spectra clearly shows that all the programme stars have absolute magnitudes between those of GJ1002 ($M_v = +15.5$, ref. 8) and vB10 ($M_v = +18.5$, ref. 9). No star is significantly fainter than vB10, although one star for which we do not yet have a spectrum has redder optical colours. In the survey reported in refs 5 and 6, which was restricted to a volume a factor of ~30 smaller than the present survey, we also found just one star of very low luminosity (RG0050.5−2722, $M_v \sim +19$, refs 10, 11). An increase of a factor of about 30 has, therefore, not sampled any deeper into the luminosity function, implying either that those stars detected to date are the faintest which exist, or that the space density of objects less luminous than $M_v \sim +19$ is substantially below that of more luminous stars. In either case we may conclude that low-mass luminous stars do not contribute significantly to the total mass density in the solar neighbourhood, and are not a viable candidate for the local missing mass. Further discussion of the local mass function is given in refs 5 and 6.

The second result of this survey is that the surface density of stars with $M_v \gtrsim +16$ and $I \leq \sim 18$ is near 1.0 ± 0.5 per square degree, with the uncertainty being a liberal estimate based on the uncertainties in our magnitude calibration and photometry at these magnitudes. This surface density corresponds to a space density of $\leq 10^{-2}$ pc^{-3} at the Sun. We may compare this with the values necessary to provide the local or global missing mass.

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