



Figure 19. Observational estimates of the star formation history of the Universe. The points with error bars show estimates of the mean star formation rate per unit volume at various redshifts (see Steidel et al. 1999 and references therein). The solid symbols are the star formation rates implied if there is no absorption by dust. The open symbols show estimates corrected for dust absorption using a Calzetti (1999) extinction law with a mean $E(B - V) = 0.15$ (Steidel et al. 1999). In both cases an $\Omega_0 = 0.3$, $\Lambda_0 = 0.7$ cosmology has been used to calculate the volume as a function of redshift and a Salpeter IMF to convert luminosity to star formation rate. The smooth curves are the fits we use when we integrate over time to estimate the total mass density of stars formed at the present.

that the IMFs we consider assume that only stars with mass greater than $0.1 M_\odot$ ever form and so we are not accounting for any mass that may be locked up in the form of brown dwarfs.

Our results are presented in Fig. 18 which shows both SWML and Schechter function estimates of the present-day galaxy stellar mass function for two choices of IMF. The SWML estimates are tabulated in Table 4. Just as for the luminosity functions, the stellar mass function is well described by the Schechter functional form. Integrating over these Schechter functions to determine the total stellar mass gives $\Omega_{\text{stars}} h = (1.4 \pm 0.21) \times 10^{-3}$ for the Kennicutt IMF and $\Omega_{\text{stars}} h = (2.6 \pm 0.39) \times 10^{-3}$ for the Salpeter IMF. Note that the integral converges rapidly at both limits and, in particular, the contribution to Ω_{stars} from objects with $M_{\text{stars}} < 10^9 h^{-2} M_\odot$ is negligible. We find that these values vary by less than the quoted errors when we alter the assumed (k+e) - corrections by either ignoring evolution, dust or changing Ω_0 . Taken together with our estimates of the K_S -band luminosity density these estimates imply mean stellar mass-to-light ratios of $0.73 M_\odot/L_\odot$ in the case of the Kennicutt IMF and $1.32 M_\odot/L_\odot$ for the Salpeter IMF. If we apply the correction we estimated in Section 2.3 to transform 2MASS Kron into total magnitudes, then these estimates and their uncertainties increase to $\Omega_{\text{stars}} h = (1.6 \pm 0.24) \times 10^{-3}$ for the Kennicutt IMF and $\Omega_{\text{stars}} h = (2.9 \pm 0.43) \times 10^{-3}$ for the Salpeter IMF. Both of these estimates are consistent with the value, $\Omega_{\text{stars}} = (3.0 \pm 1.0) \times 10^{-3}$, derived by Sali & Persic (1999) but have fractional statistical errors which are several times smaller. With our method, the uncertainty in Ω_{stars} is clearly dominated by the uncertainty in the IMF. For some purposes, it is not possible to improve upon this without a more precise knowledge of the true IMF - assuming that there is a universal IMF. However, for other applications, such as modelling the star formation history of the universe, it is necessary to assume a specific IMF to convert the

Table 5. Estimates of the present-day mass in stars and stellar remnants obtained by integrating over observational estimates of the star formation history of the Universe. We express this stellar mass density in terms of the critical density and give values of $\Omega_{\text{stars}} h^2$ estimated for different assumed IMFs and dust corrections. All values are for an $\Omega_0 = 0.3$, $\Lambda_0 = 0.7$ cosmology and assume stellar populations of solar metallicity.

Dust extinction	Kennicutt IMF	Salpeter IMF
$E(B - V) = 0.05$	0.80×10^{-3}	1.30×10^{-3}
$E(B - V) = 0.10$	1.17×10^{-3}	1.86×10^{-3}
$E(B - V) = 0.15$	1.63×10^{-3}	2.66×10^{-3}

observational tracers of star formation to star formation rates. Hence, in this case, it is the much smaller statistical errors that are relevant.

It is interesting to compare our values with what is inferred by integrating the observational estimates of the mean star formation history of the Universe. Fig. 19 shows observational estimates for one particular choice of cosmology and IMF, and illustrates how the rates are sensitive to the assumed dust extinction. By fitting a smooth curve through these estimates, we can calculate the mass of stars formed by the present day and how this depends on the IMF and assumed dust extinction. The upper smooth curve shown in Fig. 19 is of the form $\dot{\rho}_* = (a + bz)/[1 + (z/c)^d] h M_\odot \text{ yr}^{-1} \text{ Mpc}^{-3}$, where $(a, b, c, d) = (0.0166, 0.1848, 1.9474, 2.6316)$. The data points uncorrected for dust extinction are fit with $(a, b, c, d) = (0.0, 0.0798, 1.658, 3.105)$. As for our estimates above, we assume that no mass goes into forming brown dwarfs and multiply the star formation rate by $1 - R$, where R is the recycled fraction, so as to form an estimate of the mass locked up in stars. Values of $\Omega_{\text{stars}} h^2$ estimated in this way are listed in Table 5. The values in this table are for an $\Omega_0 = 0.3$, $\Lambda_0 = 0.7$ cosmology, but they are insensitive to this choice. They depend slightly on the assumed metallicity of the stellar population, and would be 10 per cent lower if the half solar, rather than solar metallicity were assumed. Note that the Ω_{stars} values inferred from the star formation history of the Universe scale differently with the assumed Hubble constant than those inferred above from the IR luminosity functions. For $h = 0.7$ our estimates from 2MASS become $\Omega_{\text{stars}} h^2 = (1.12 \pm 0.16) \times 10^{-3}$ for the Kennicutt IMF and $\Omega_{\text{stars}} h^2 = (2.03 \pm 0.30) \times 10^{-3}$ for the Salpeter IMF. Comparison with Table 5 shows that these values are consistent with those inferred from the cosmic star formation history only if the dust correction assumed in the latter is modest, $E(B - V) \approx 0.1$. This value is 50 per cent smaller than the value preferred by Steidel et al. (1999).

6 CONCLUSIONS

The new generation of very large surveys currently underway make it possible to characterize the galaxy population with unprecedented accuracy. In this paper, we have combined two such large surveys, the infrared imaging 2MASS and the 2dF Galaxy Redshift Survey¹ to obtain a complete data set which is more than an order

¹A table containing the positions, 2MASS infrared magnitudes and 2dFGRS redshifts used in this paper, and electronic versions of Tables 2 and 4 are available at <http://star-www.dur.ac.uk/n~cole/2dFGRS-2MASS>.