COSMIC SPECTRA AND STAR–FORMATION HISTORY

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Introduction

The analysis of the comoving star–formation rate density as a function of redshift, "cosmic star–formation history", has been the subject of much recent work. The onset of large redshift surveys out to z~4.5 has allowed the volumetric emission of luminosity in different bands to be traced with redshift. In particular, from these studies there is now good evidence for a rise in star–formation rate by a factor of about eight between z=0 and z=1 (Hogg 2002) and either a z>1 decline or plateau (Madau et al. 1996; Pettini et al. 1998).

Most measurements of the star–formation rate (SFR) to date have been based on some type of *luminosity density* which is thought on theoretical and/or empirical grounds to trace the SFR. This use of luminosity per unit volume reflects an attempt to decouple the stellar history of the Universe from its dynamical history.

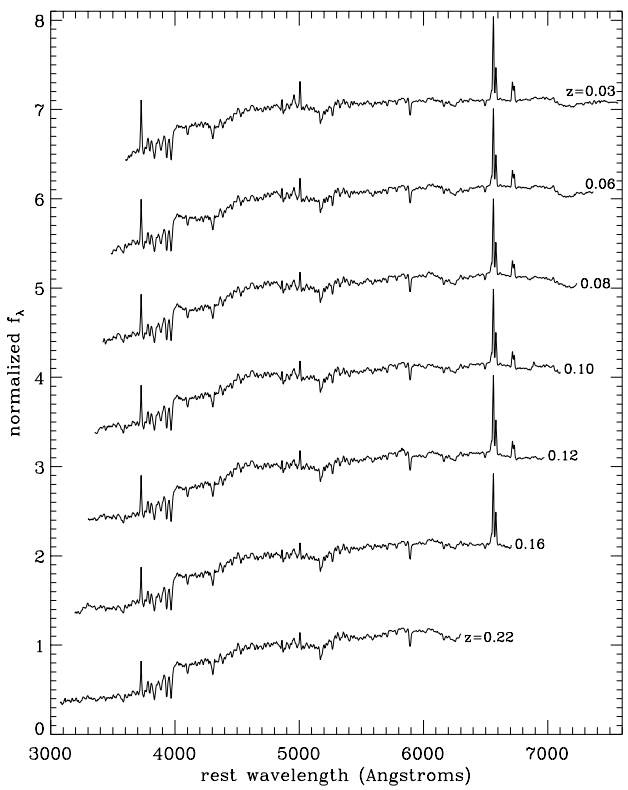

Figure 1. Cosmic spectra from various redshift bins measured using 2dFGRS data. The spectra were normalized and offset by unity from each other. Each is a weighted mean spectrum of over 10 000 galaxies. The features look remarkably similar other than for an increase in nebular emission at low redshift due to luminosity–selection effects.

Popular tracers of SFR include: the UV continuum from short–lived OB stars; the radio continuum from supernovae; and line emission from nebular regions.

Other than direct tracers of the SFR, cosmic star–formation history (SFH) can be constrained by using the fossil record of stars visible today. For example, the SFH of the Local Group (Hopkins et al. 2001) has been shown to agree approximately with the cosmic SFH derived from UV measurements. However, the SFH of the Local Group is not representative of the low redshift cosmos, being dominated by two galaxies – the Milky Way and M31. The data from the 2dF Galaxy Redshift Survey (Colless et al. 2001) does provide a highly representative view of the cosmos. Individual stars or star clusters are not resolved but the star–formation history of the galaxies can be constrained from the spectra using evolutionary, or population, synthesis.

Cosmic spectra

We present constraints on the history of star formation based on the "cosmic spectra" of relatively nearby galaxies (z<0.3). The concept is to use the average spectrum of nearby galaxies to constrain the earlier history of star formation leading up to that stellar population. The cosmic spectra are constructed in redshift slices by coadding the individual spectra after applying an instrument–response correction, de–redshifting and weighting according to the galaxy's b_J luminosity. Examples of cosmic spectra[1] are shown in Figure 1. Each represents the spectral emission per unit volume in a $z \rightarrow z + \Delta z$ interval down to the limiting magnitude of the survey. Stellar continuum/absorption and nebular line emission are the principal components. Accretion–disk emission should contribute only a small "contamination".

Cosmic Star-Formation History

In order to constrain the cosmic SFH, we parameterized the variation of SFR with time/redshift (incorporating chemical evolution). Given a grid of star–formation histories, we then computed model spectra using the PEGASE evolutionary synthesis code (Fioc & Rocca–Volmerange 1997) and fitted the model spectra to the measured cosmic spectra.

[1] Given a cosmic spectrum at *z*~0.1, what would be the perceived colour? By integrating standard colour matching functions through the spectrum, we have computed RGB values of 0.269, 0.388 and 0.342. Thus, the colour of the universe is quite close to the standard shade "Pale Turquoise" although it is a few per cent greener. See http://www.pha.jhu.edu/~kgb/cosspec.

We first tested a physical parameterization which allows for a rise and then a fall in the SFR, or a rise in the SFR, to the present day. Despite significant age–age and age–metallicity degeneracies for the best–fitting models, all showed a peak in comoving SFR density in the past of at least three times the current rate (using the Salpeter IMFand limiting the universe age to <20 Gyr). Some best–fitting star–formation scenarios are shown in Figure 2.

In order to compare our cosmic SFH constraints with luminosity–density methods, we also tested an empirical SFR parameterization. In particular, we made the star-formation rate between z=5 (our choice of formation redshift) and z=1 proportional to $(1+z)^{\alpha}$ and between z=1 and z=0 proportional to $(1+z)^{\beta}$, with matched SFR at z=1. There is a strong upper limit of $\beta < 5$ for the best-fitting models, allowing for a large range of metallicity with the Salpeter or Kennicutt IMF. The upper limit on β is lowered if there is any significant quantity of star formation prior to z=1 (e.g., β<4 if α>-3).

We compared our results with two different compilations of cosmic SFH based on the rest–frame UV luminosity–density technique and with a compilation of various other techniques. The α–β empirical parameterization was fitted to the data sets after converting to the standard cosmology. Various confidence–limit contours are shown in Figure 3.

The difference in the confidence limits of the two UV compilations reflects a recent debate over the value of β (1.5 versus 4). However, given the errors used in our analysis (minimum of 15% in each luminosity density), they are in agreement at the 3σ level and our results are independently consistent with that intersection (1.8<β<2.9 and -1.0<α<0.7).

For more details, see Baldry et al. 2002.

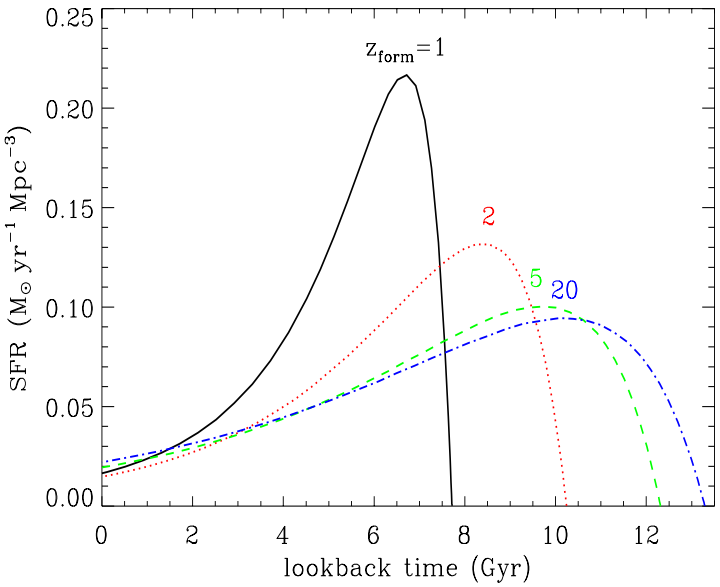

Figure 2. Example set of star-formation histories that fit the measured cosmic spectra using the physical parameterization. The formation redshifts shown are for the standard cosmology with (H_0, Ω_{m_0}, Ω_{Λ_0}) = (70,0.3,0.7). In these scenarios, 75-85% of stars formed prior to 4 Gyr ago.

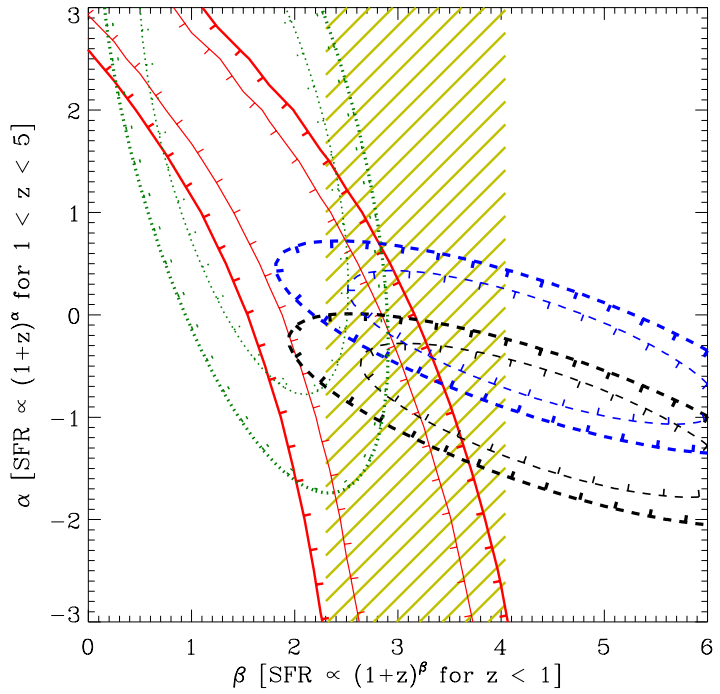

Figure 3. Comparison between different cosmic SFH studies: confidence limits in α versus β. The *solid contours* represent the 2σ and 3σ confidence limits from 2dFGRS measured cosmic spectra. The *dashed contours* represent the limits from a compilation of UV luminosity–density measurements with a z range of 0.2–4.5 (Steidel et al. 1999). The lower and upper contours are for "no extinction" and "extinction corrected". The *dotted contours* show the limits from a UV compilation with a z range of 0–1.5 (Cowie et al. 1999). The *diagonally shaded region* represents the 1σ bootstrap confidence on β from a compilation of various techniques including nebular-line emission, far infrared and radio continuum measurements with a z range of 0–1 (Hogg 2002).

References

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