Evidence for Short-Lived SN-IA Progenitors

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List of SN hosts at http://sn.aubourg.net/hosts/

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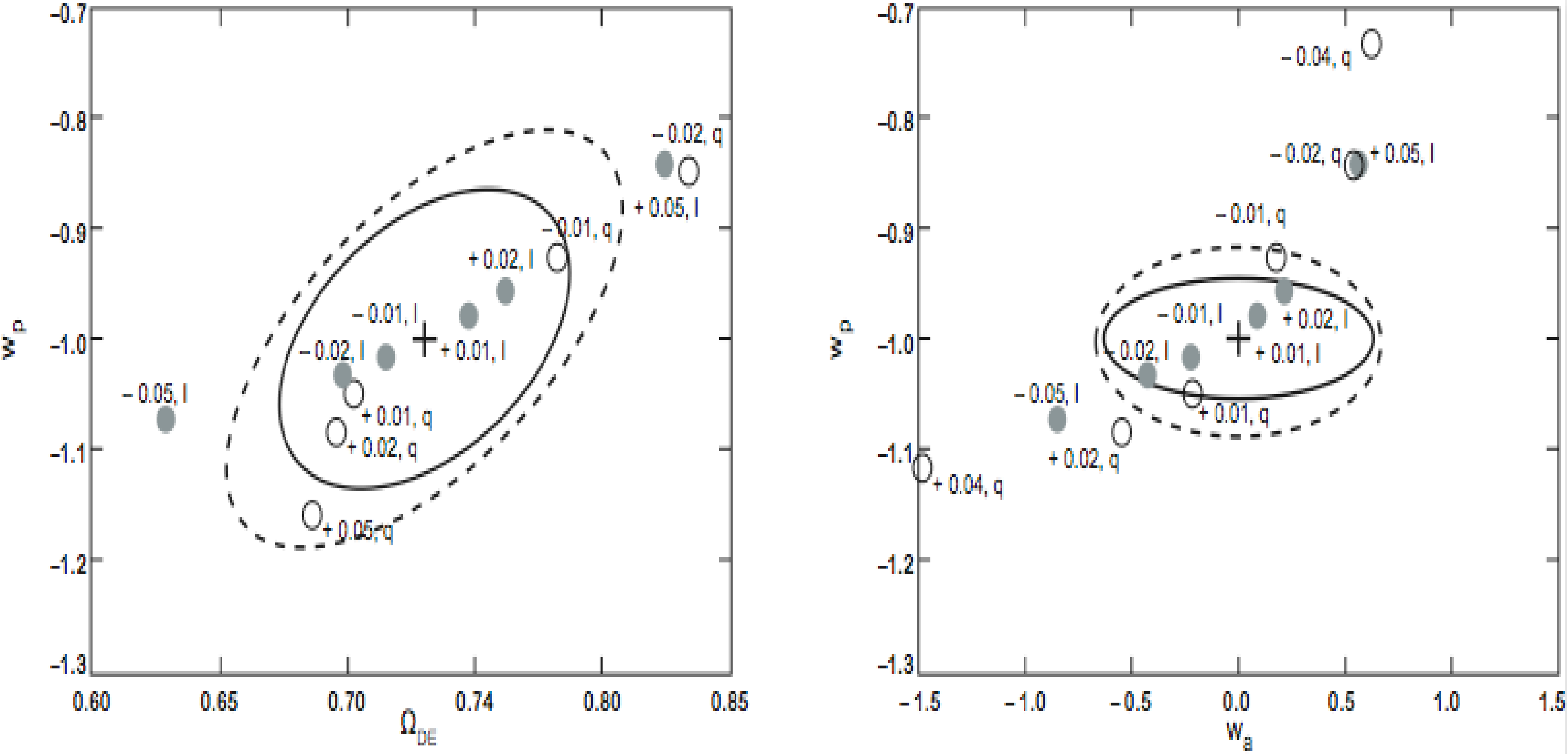
(Aubourg et al. 2007 arXiv:0707.1328)

The relationship between peak brightness and redshift of Type-Ia supernovae depends on the cosmological model; this has provided the most direct evidence for the accelerated expansion of the universe.

The natural scatter in SNe Ia peak luminosity covers roughly one magnitude; the rms peak luminosity is 0.45 mag after excluding outliers. Empirical correlations based on light curve shape or intrinsic color allow reduction of this scatter to about 0.13 mag, making them usable for cosmological measurements.

However, it is not yet known how much of the residual scatter is correlated with physical parameters that could evolve with redshift, and thus bias the cosmological measurements.

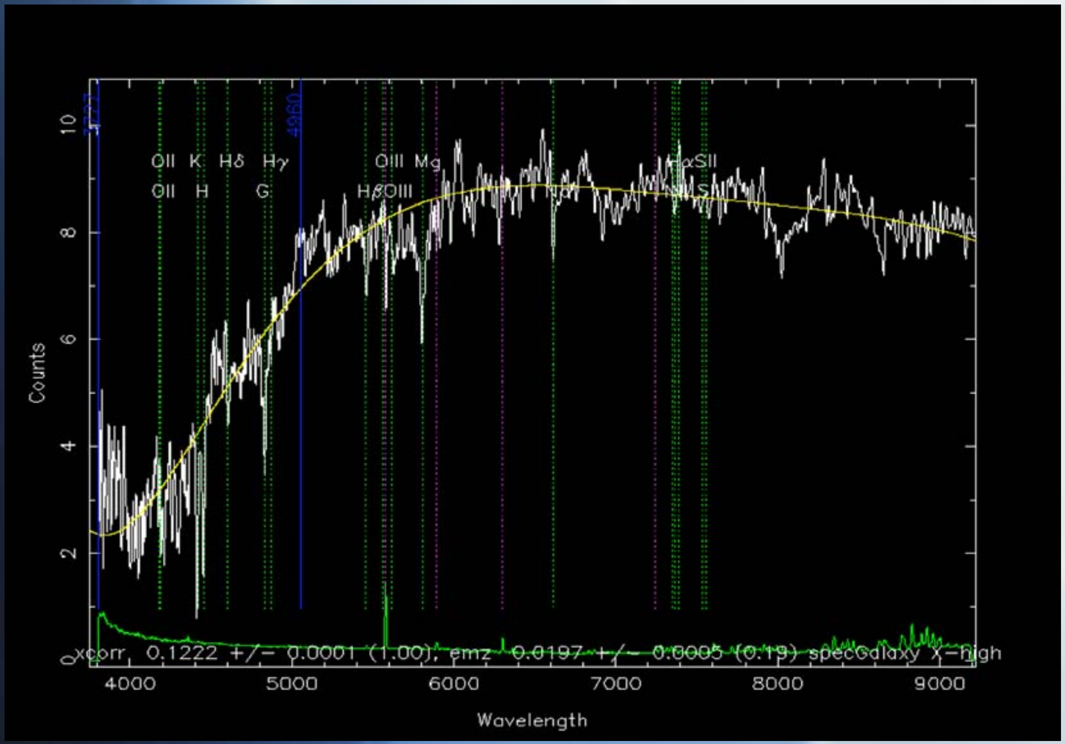
Effect of a SN luminosity bias correlated with redshift on the determination of the dark energy parameters Omega_E, wp and wa as defined in the DETF report. The black ellipses are taken for a SNAP-like experiment. They correspond to the 95% C.L. (left) or one-sigma (right) error for the two DETF hypotheses on the error budget, pessimistic (dashed line) or optimistic (solid line). We added the displacement in best fit value produced by a bias either linear (l, filled gray circles) or quadratic (q, open circles) in redshift. The quadratic bias peaks at $z = 1$. The value next to each dot is the magnitude difference at $z = 1$ (-0.05 to 0.05). Metallicity effects, for instance, are expected to behave like a quadratic bias with positive values (Timmes et al. 2003, Podsiadlowski et al. 2006), and one can clearly see from this figure that they must be understood at the percent level not to dominate the measurement error budget

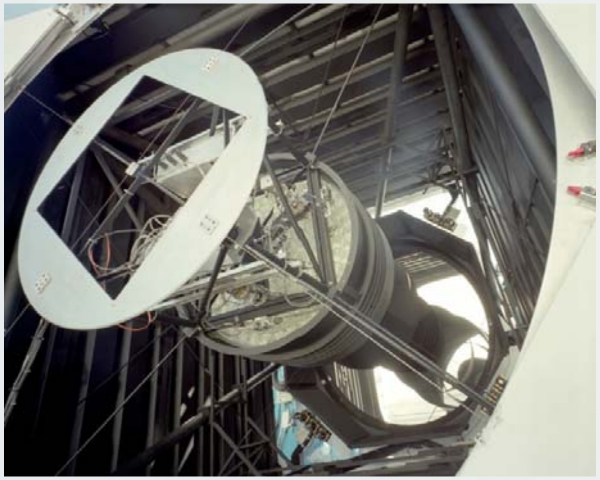


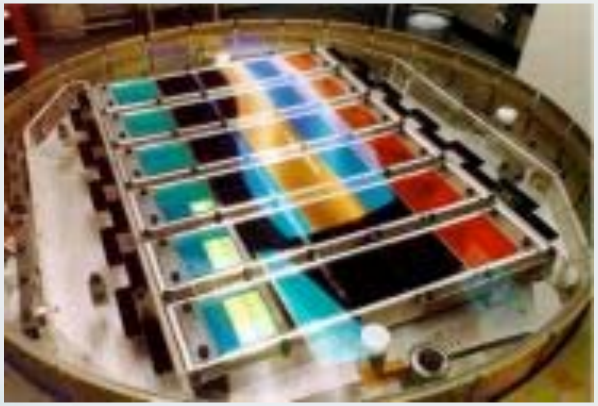
VESPA: a new tool to study stellar populations

Idea is to determine the past Star Formation History of the SN host galaxy and see if it correlates with SN activity.

SDSS: Largest data-set of galaxy spectra (about one million of them)

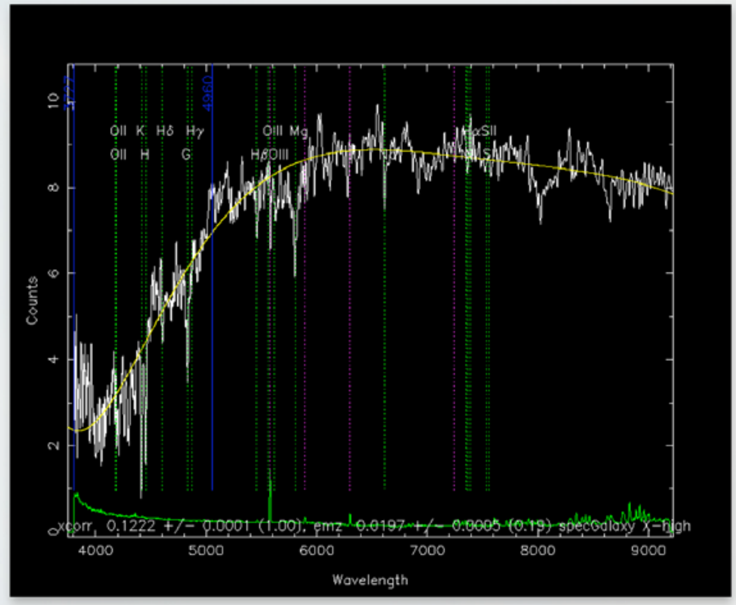


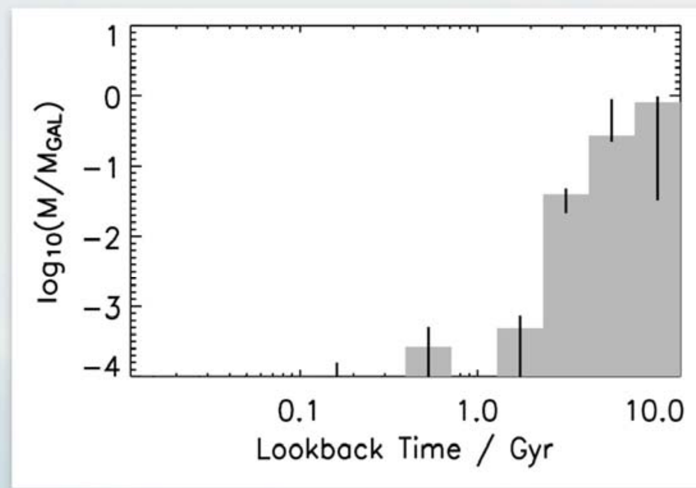




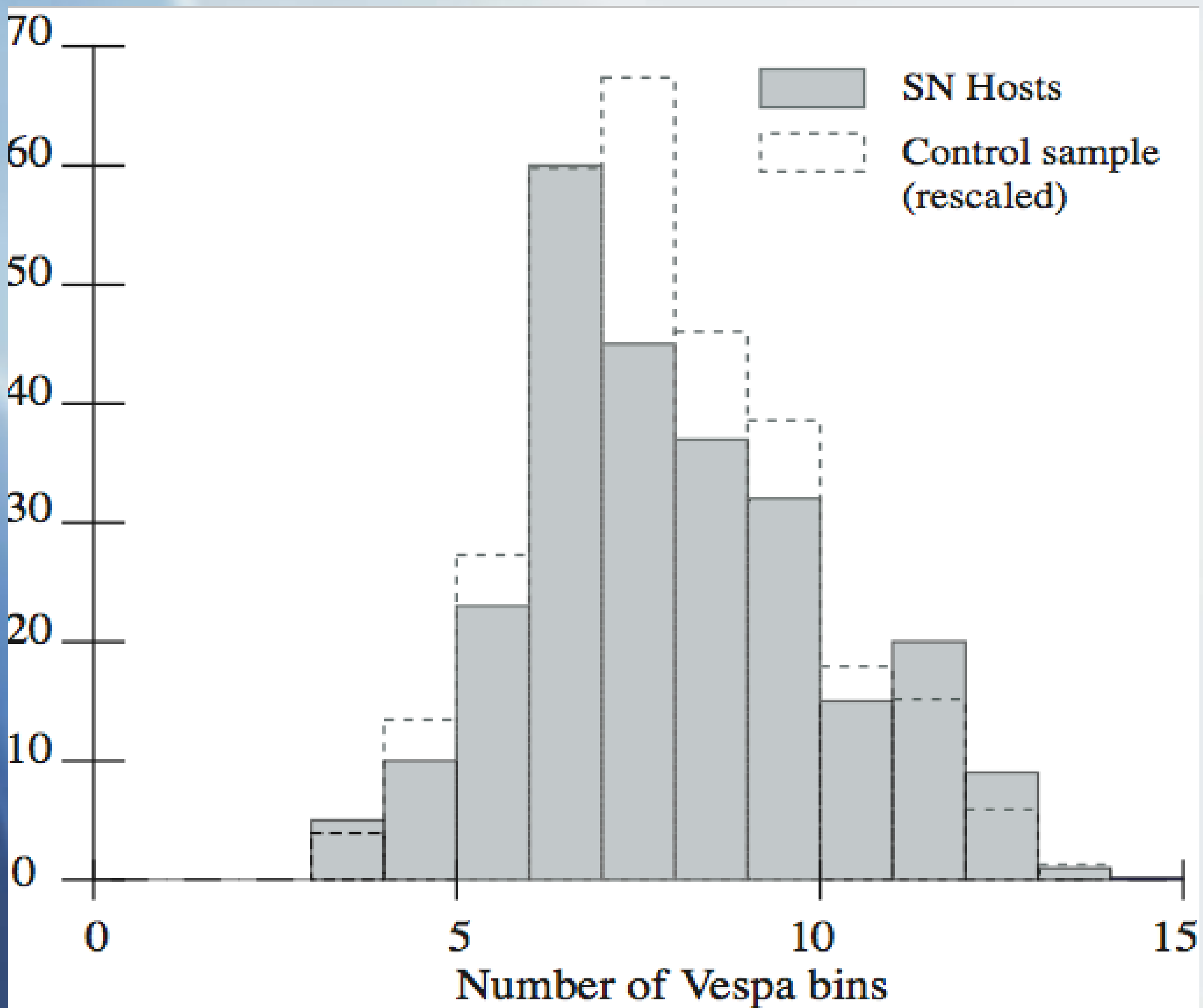
Characterising the SFH

- Current models and data allow the star formation rate and metallicity to be determined in around 8-12 time bins
- 10 x 2 + 1 dust parameter = 21 parameters – significant technical challenge
- To analyse the SDSS data would take ~200 years
- Needs some way to speed this up by a large factor
- We use VESPA



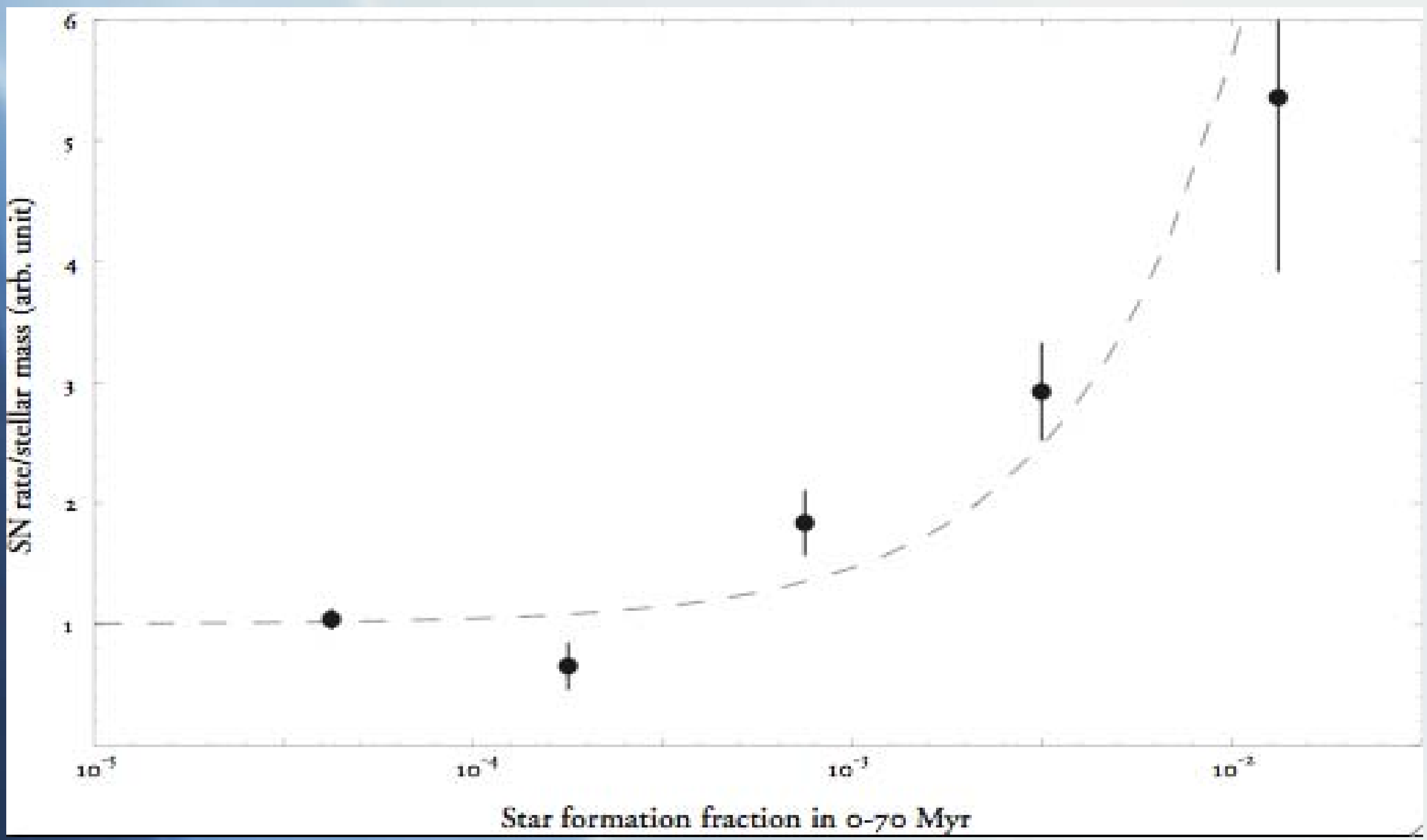


Distribution of the number of bins reconstructed by VESPA on the host sample (grey) and the control sample (dashed white). By design, VESPA merges bins with more than 10% ``leakage'', down to a minimum of three bins. For most galaxies VESPA is able to recover a larger number of bins, which makes us confident that our 0-70 Myr bin does not suffer contamination from older populations by more than 10%

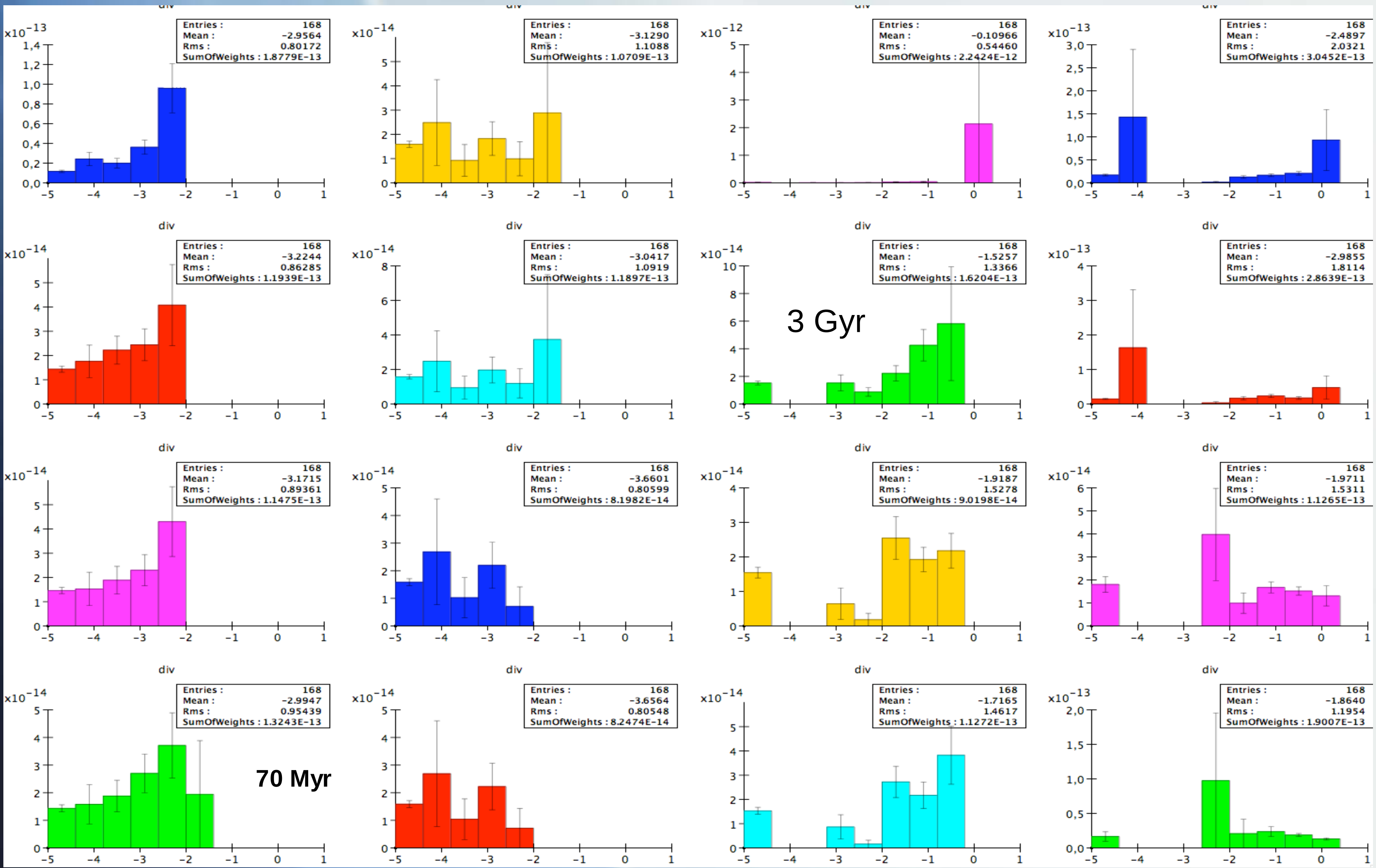


One of the products of VESPA is the fractional stellar mass formed in each time bin in a given galaxy. Given any time interval corresponding to one or more VESPA age bins, we can build a histogram of the number of SN hosts in bins of this star formation mass function. On the control sample, we can build a similar histogram of total stellar mass in the same bins. The quotient of those histograms represents, in each star formation fraction bin, the ratio of supernova rate to total stellar mass, up to a global normalization.

Binning over the four most recent VESPA bins, i.e. age < 70 Myr, we plot the resulting rate in the Figure below. For each range of mass fraction, the data points show the supernova rate per stellar mass for host galaxies having formed that fraction of stars in the last 70 Myr.



The correlation becomes weaker when larger ages (> 70 Myr) are included.



Conclusions

In analogy to Sullivan et al. (2006), we fit a two-component model to these data, SNR = alpha x M+ beta x M70, where M is the total stellar mass and M70 is the mass formed in the last 70 Myr. Since we do not evaluate the efficiency, we can only measure beta/alpha: we find beta/alpha = 465±83, which is a five-sigma evidence for a short duration component. The result is presented for 0-70 Myr because this is the most significant correlation we find. The ratio beta/alpha we find is compatible with previous estimates for which the “recent” SFR is estimated in general from colors (Neill et al. (2006) & Scannapieco & Bildsten (2005) find beta/alpha from 400 to 840.

In accordance with the findings of several authors (Mannucci et al. 2005, Mannucci et al. 2006, Sullivan et al. 2006), we have shown that SNe Ia can occur through short-lived progenitors, hinting at a variety of stellar evolution paths with different lifetimes.

Such a short time delay strongly constrains the nature of possible progenitors. They must be stars that evolve fast enough, i.e. with a mass above 6 $M_\odot$, but must be below the super-AGB mass threshold (about 8 $M_\odot$) above which one gets electron-capture supernovae (Poelarends et al. 2007). Pinsonneault & Stanek (2007) have also suggested that a significant fraction of binaries are twins (i.e., pairs of stars with essentially identical masses), and that such twin binaries could produce a short (< 0.1 Gyr) path to SN Ia.

If one assumes stars between m1 and m2 yield prompt Type 1a SNe with an efficiency e1 and stars above m2 yield Type 2 SN with an efficiency e2 , then for an IMF of the form $N(M) \propto M^{-\alpha}$ the rate ratio of prompt Type 1a to Type 2 is $e1/e2 - m1/m2\ \alpha{-}1$, i.e. 0.3 e1/e2 for a Salpeter α = 2.35 IMF, m1 = 6 $M_\odot$ and m2 = 8 $M_\odot$. The efficiencies are of course not well known but there seems to be enough progenitors to account for the observed rate.