The ages of HII galaxies

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Estalli22 IAA, Enero 2004

How old are the youngest VSF systems, i.e. the HII galaxies?

What are the expectations regarding the spectral evolution
of HII galaxies or HII regions or Starbursts?

We can learn a bit from computations that combine stellar evolutionary synthesis with photoionization.

Coeval population after Leitherer & Heckman (1995),

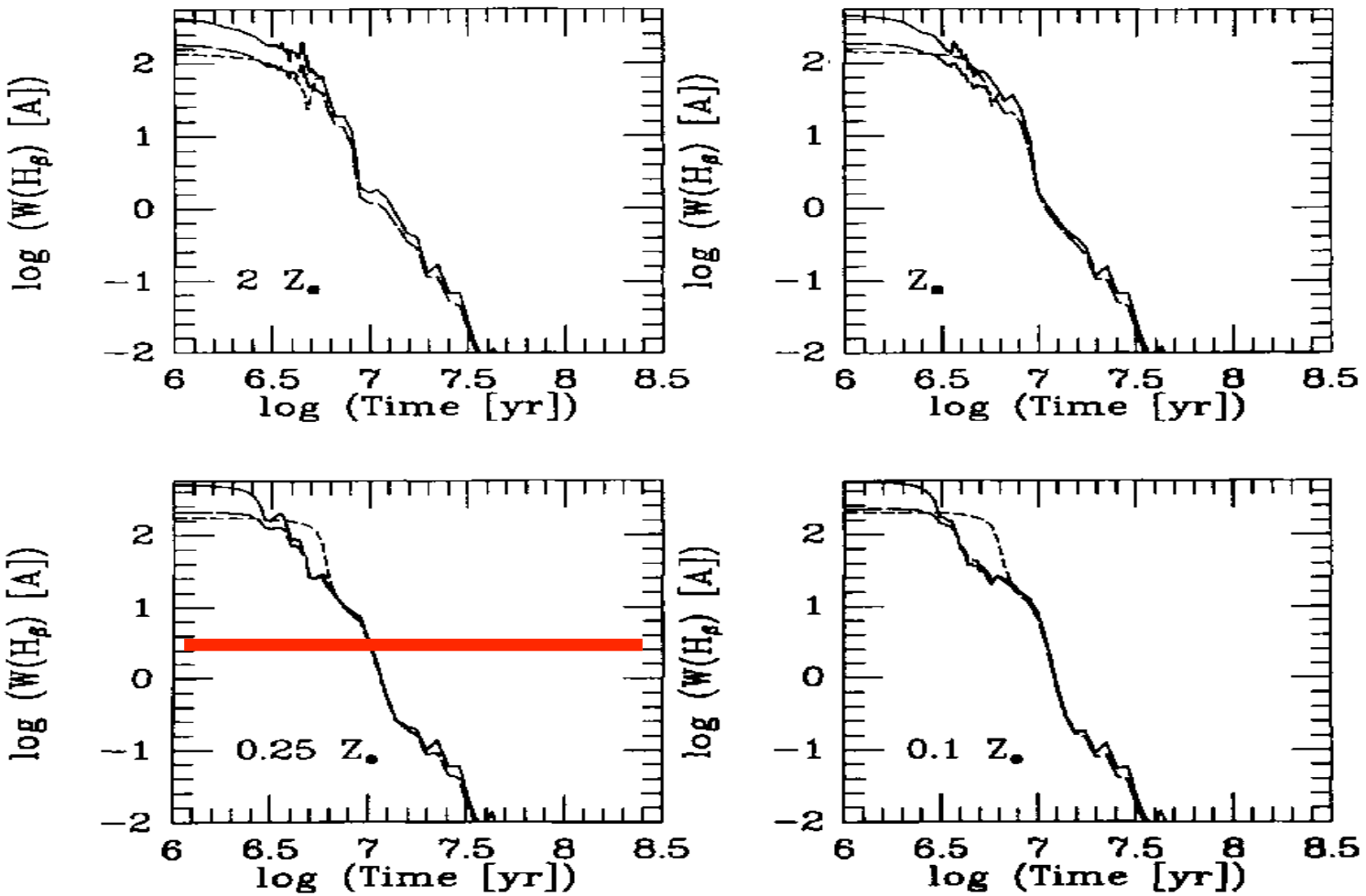


FIG. 45.—Equivalent width of Hβ vs. time for an instantaneous burst. Parameters as in Fig. 1.

Continuous star-formation

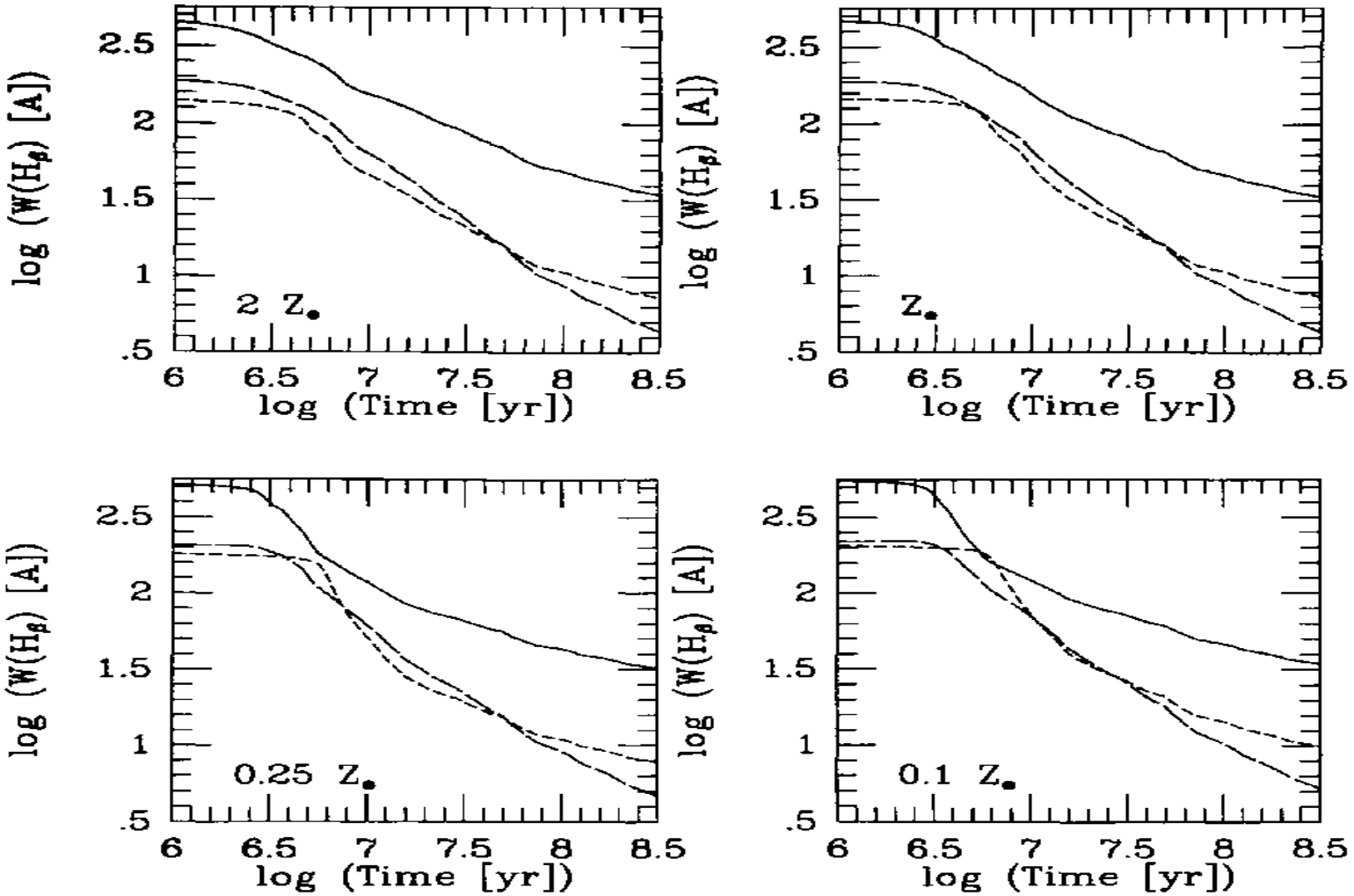


FIG. 46.—Equivalent width of Hβ vs. time for a continuous star-formation rate. Parameters as in Fig. 2.

Dottori (1981) suggested the use of the Equivalent Width of H_ to detect differences in age among HII regions.

Dottori and Bica (1981) applied the method to LMC & SMC HII regions.

The uneven distribution of ages suggested a galaxy wide burst of star formation 6 to 7 Myr ago.

The problem is that in most if not all the samples we have looked, there is a similar uneven distribution characterized by a relative lack of young systems.

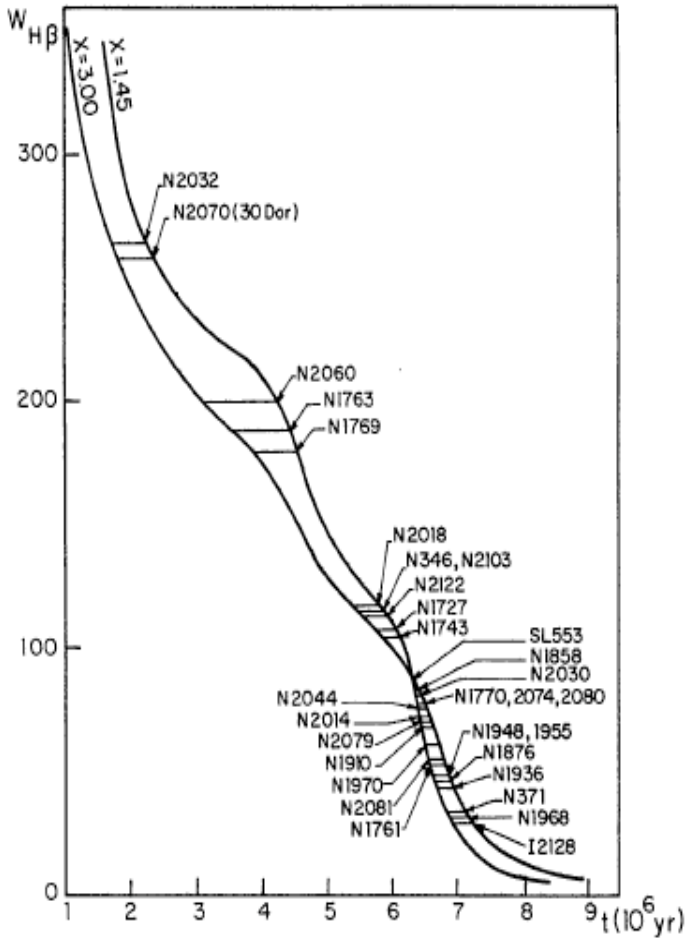


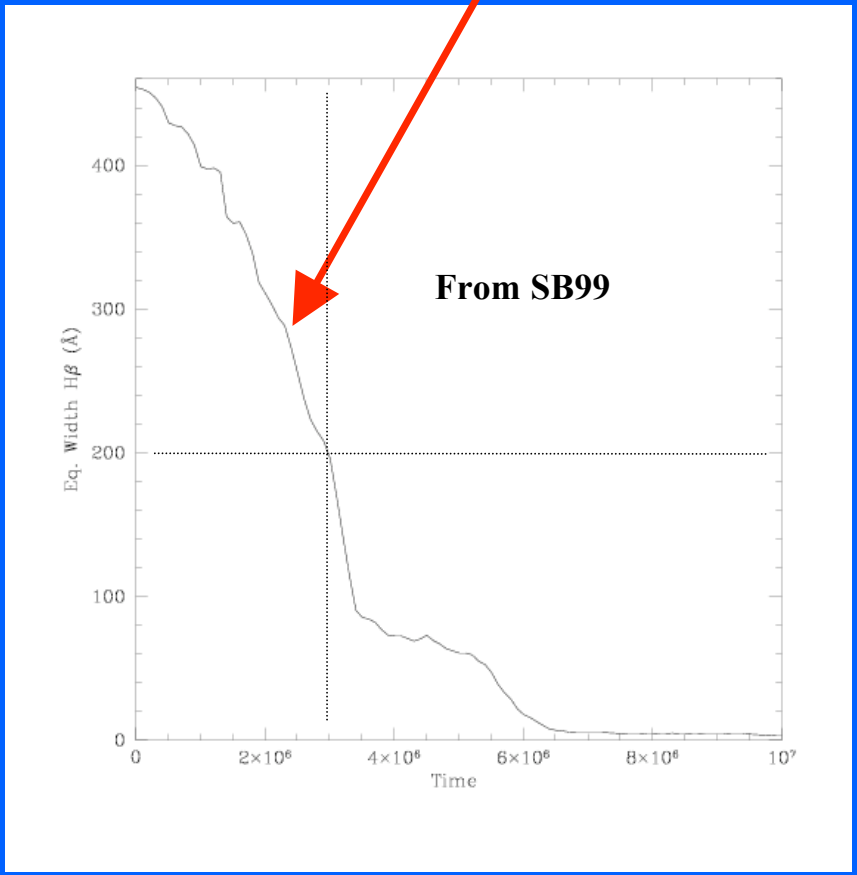
Fig. 1. Age determination of H II regions in the Magellanic Clouds, where x means $\varphi(M) = M^{-(1+x)}$

The low to extremely low metal content of HII galaxies indicates that only a small amount of evolution has taken place since formation.

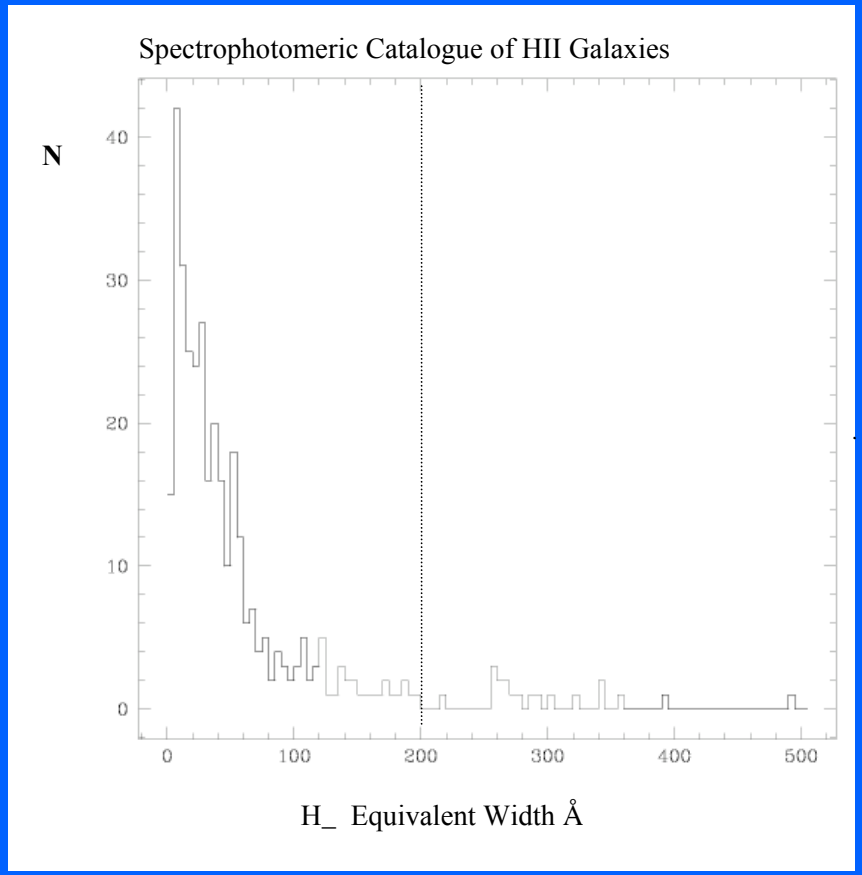
HII Galaxies are perhaps the youngest galaxies that can be studied,

but, how old are they ?

Synthesis model prediction for a coeval burst,



But surveys of strong emission line HII Galaxies find few with EqwHBeta > 200Å



For many years we argued about the possible origin of the apparent lack of strong emission line systems, and the pros and cons of the different explanations without reaching a convincing case.

In collaboration with Daniel Rosa, Sergei Silich and Elena Terlevich we applied a new approach and run on the best available datasets a new supervised method of analysis of data.

We shown that for a population of independent events that have a monotonic evolution , the probability density function is:

$$\rho_w(W) = -\frac{1}{t_{SF}} \frac{\mathrm{d}t(W)}{\mathrm{d}W}$$

With inverse transformation:

$$t(W) = -\sum_{i_{max}}^{i} t_{SF}\, \rho_i(W)\, \Delta W = \frac{t_{SF}}{N_0} \sum_{i}^{i_{max}} \Delta N_i$$

Example,

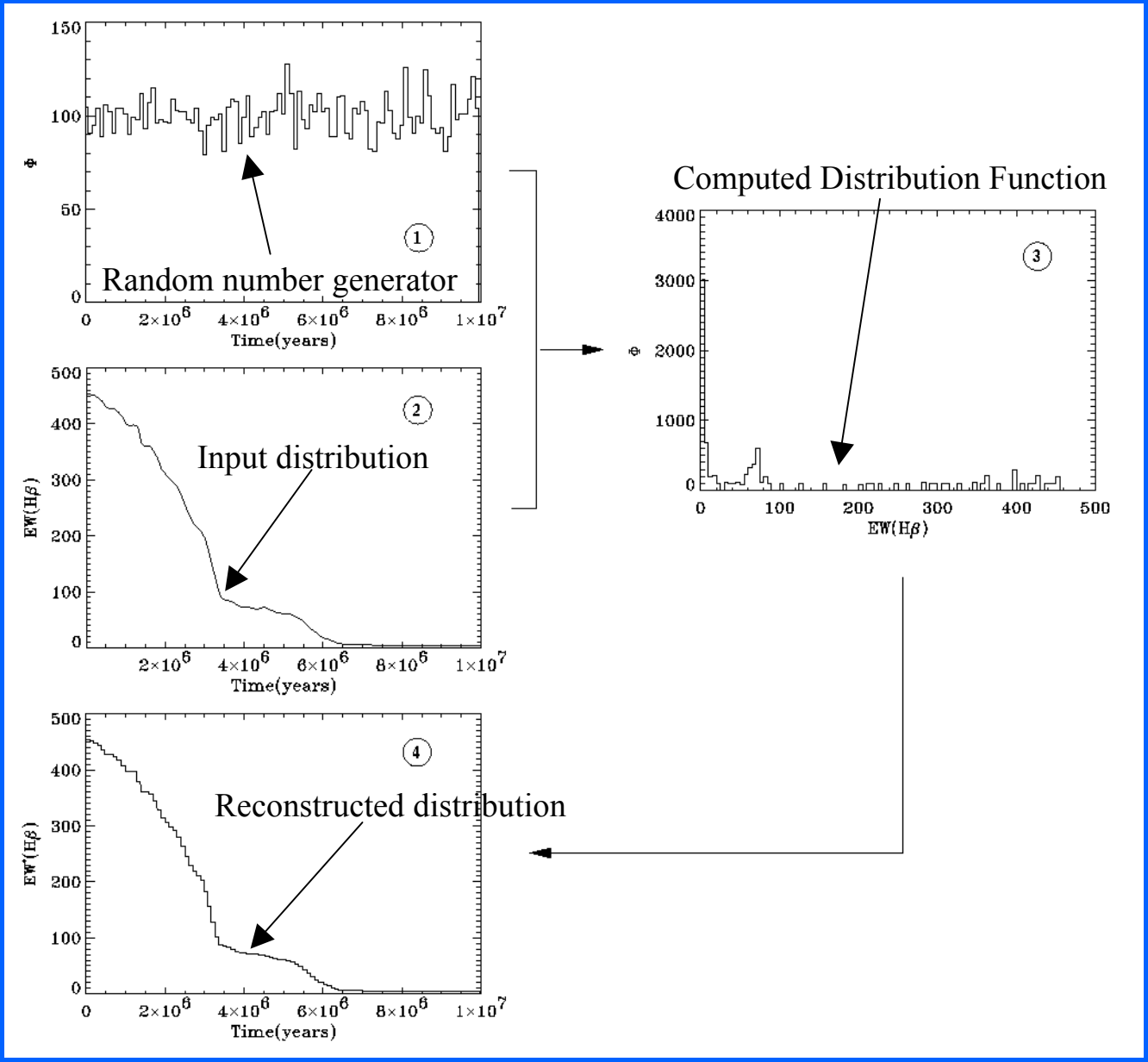
1 – We generated a sample of random numbers homogeneously distributed in time,

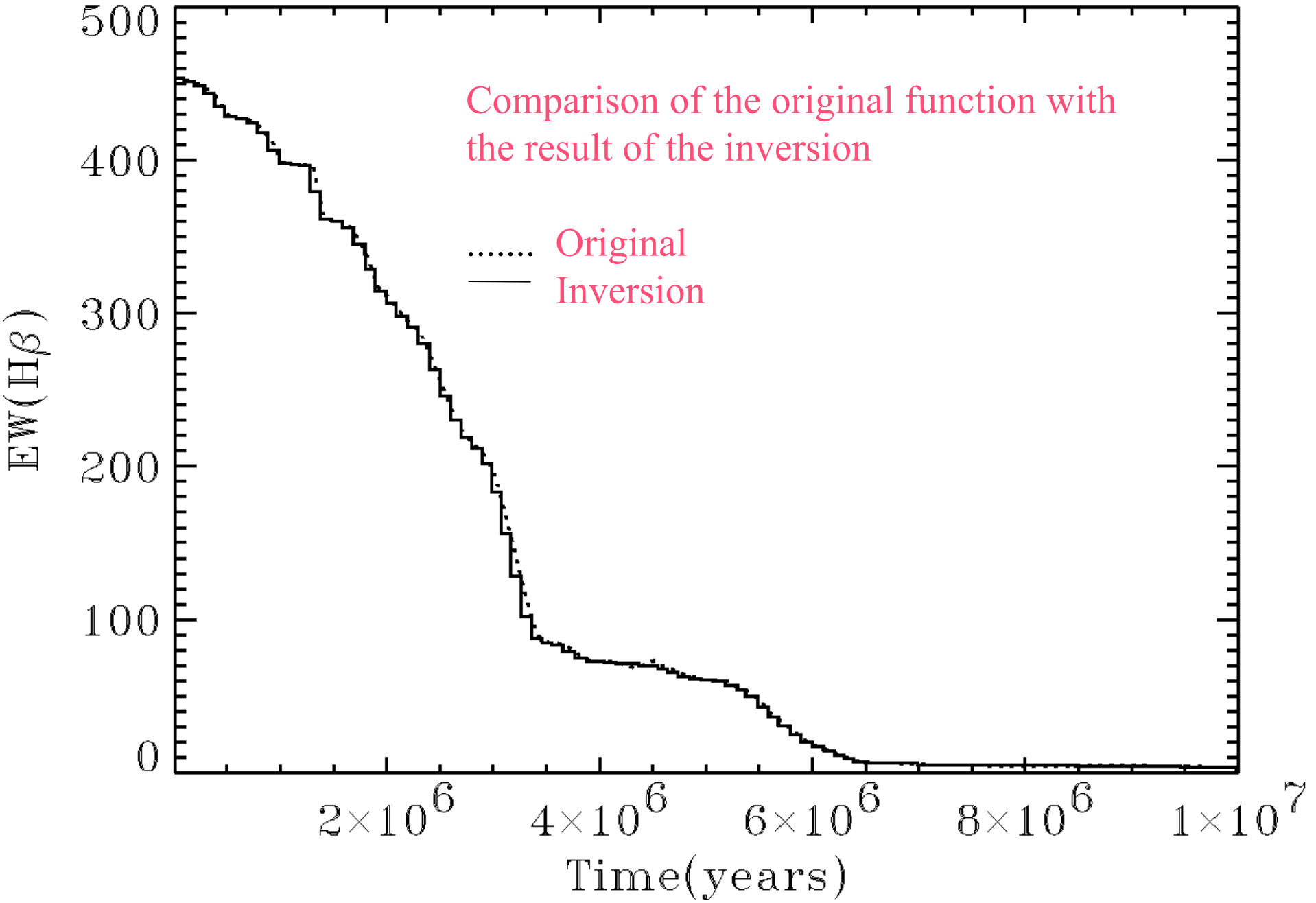
2 – For each value the corresponding equivalent width is calculated using population synthesis models,

3 – We created the distribution function of equivalent widths,

4 – The inverted distribution function reproduce exactly the assumed time evolution of the equivalent width.

The Equivalent width evolution case




Comparison of the original function with
the result of the inversion
..... Original
—— Inversion
EW(Hβ)
500
400
300
200
100
0
2×10^6
4×10^6
6×10^6
8×10^6
1×10^7
Time(years)

Thus, for samples of events that are randomly distributed in time and each of the events evolves monotonically, it is possible to recover the shape of the input distribution .

The reconstructed distribution has an undetermined scale factor.

We applied this inversion method to different samples.

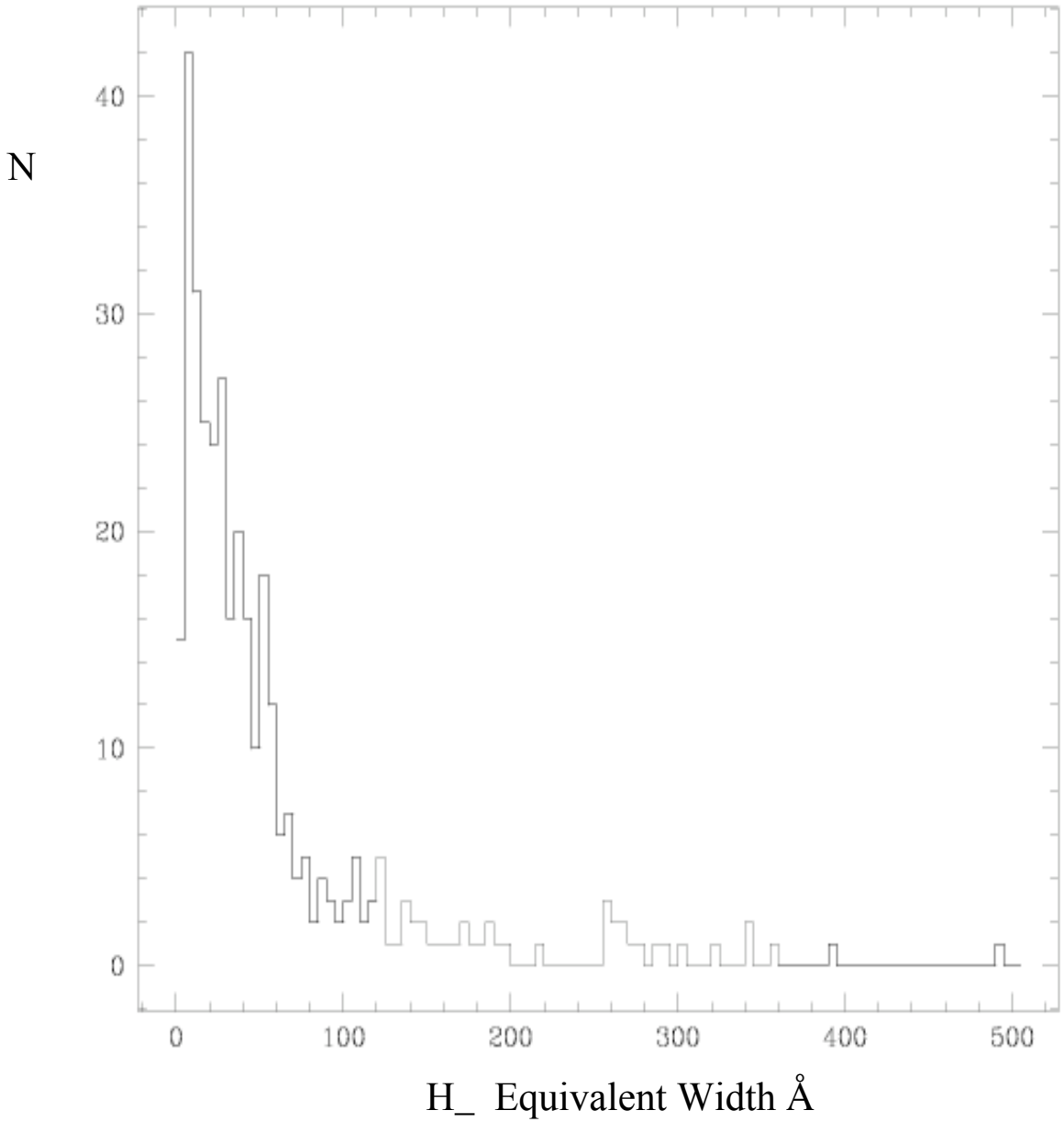
1 – SCHIIG that includes the youngest systems

2 – UCM complete sample of nearby emission line galaxies

In what follows:

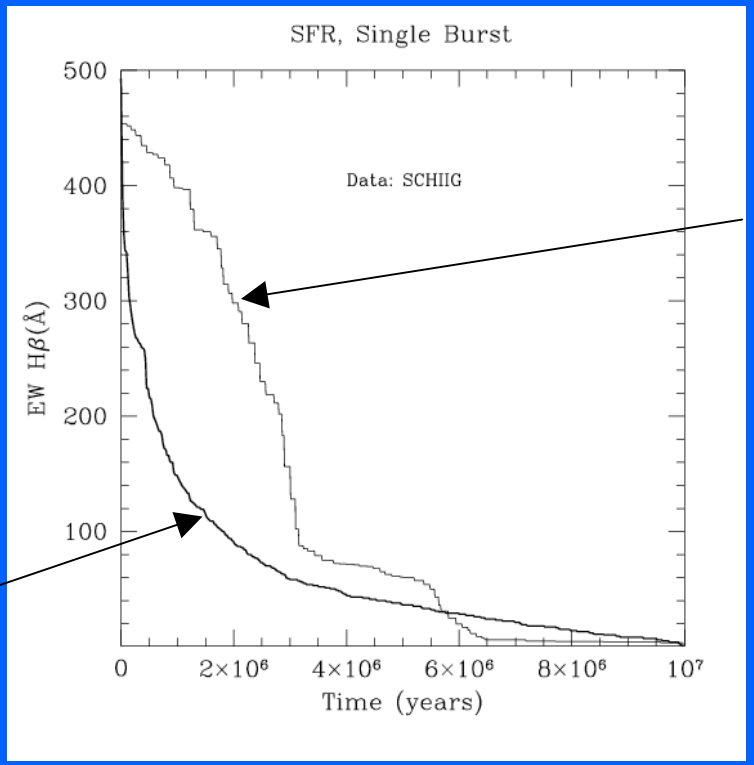
Thin lines show the model predictions for the instantanous burst and continuous star formation cases.

Thick lines show the inversion results



Observed distribution from the Spectrophotometric Catalogue of HII Galaxies.

Instantaneous SF (SCHIIG)



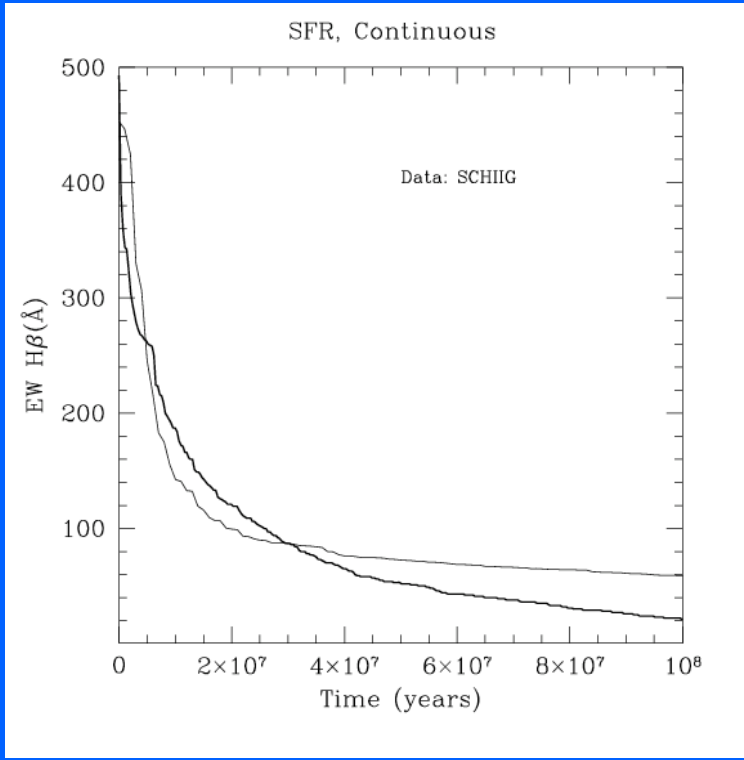
Model prediction

Inversion from data

The Single Burst model predictions do not fit the shape of the observed evolution of the Equivalent width of H_.

Their shapes are too different.

Continuous SF (SCHIIG)



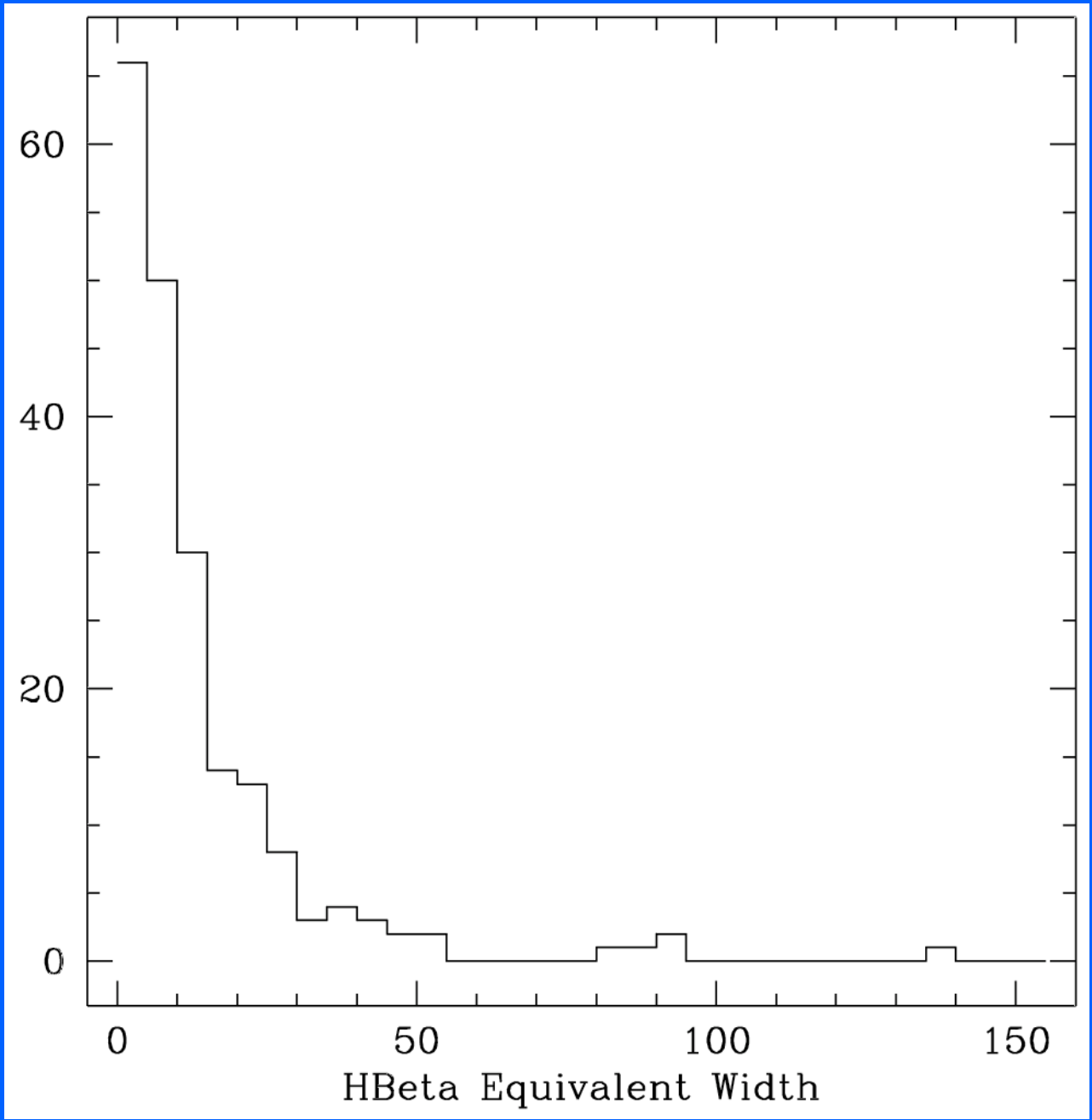
On the other hand, continuos SFR models give a reasonably good description of the shape of the TRUE time evolution of the Equivalent width of H_.

The simplest interpretation is that while the observed emission lines track the present burst, the underlying continuum contains the whole history of SF of the HII galaxy.

BUT,

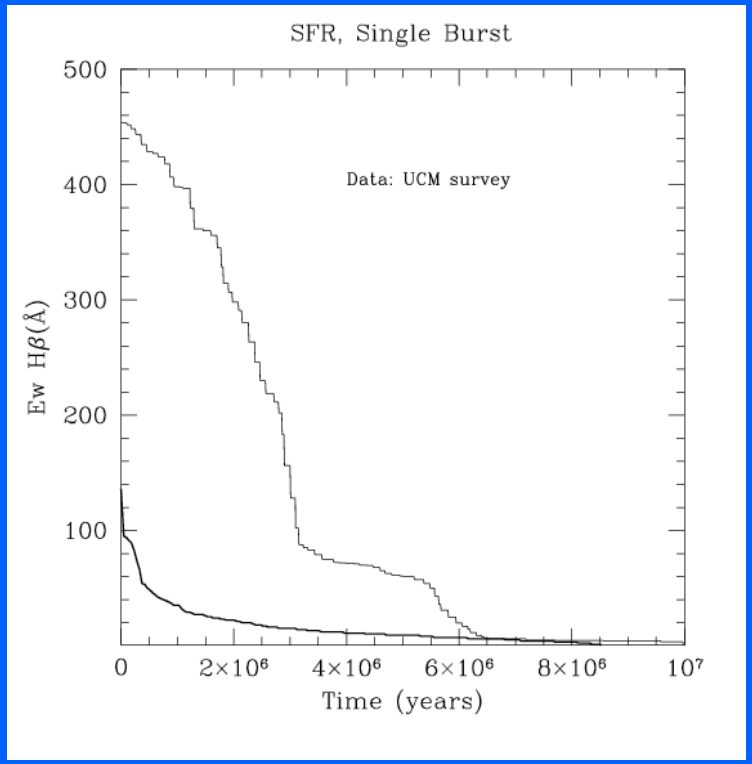
What is the situation with a different sample with different selection criteria?

We have also analysed the UCM complete sample of starforming galaxies.

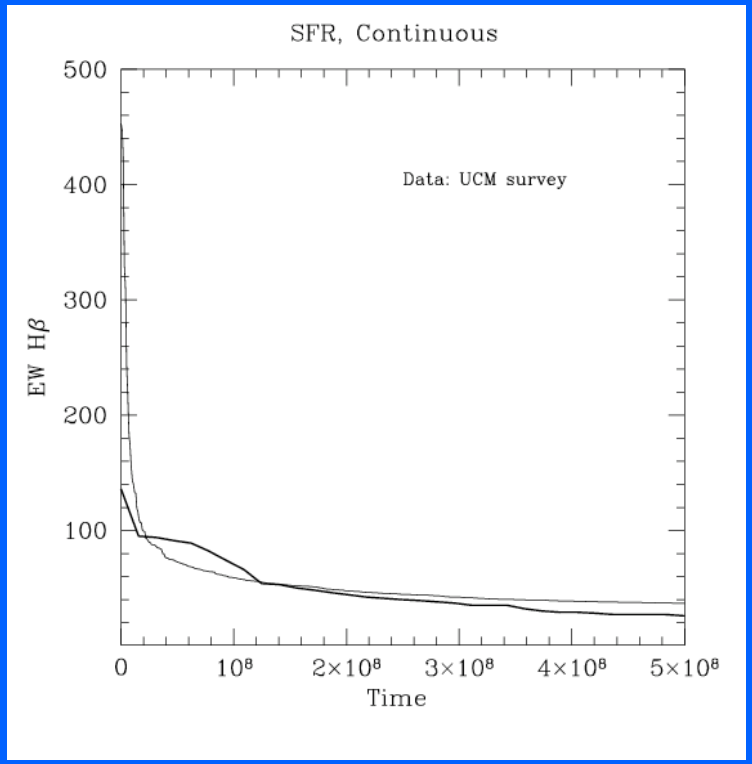


UCM sample

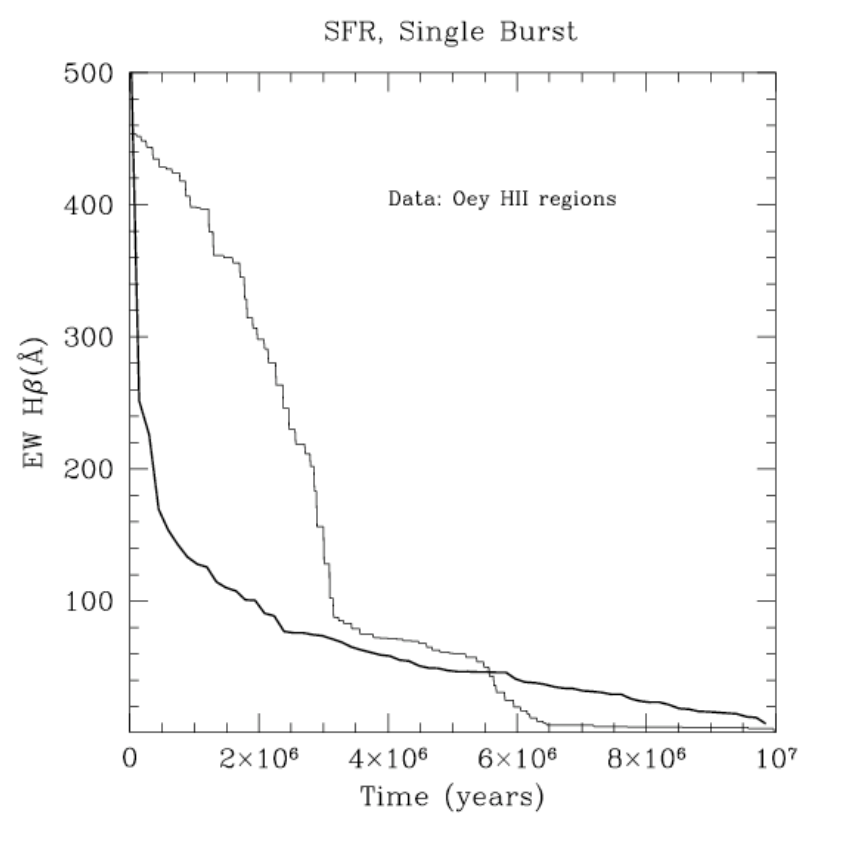
Instantaneous SF (UCM)



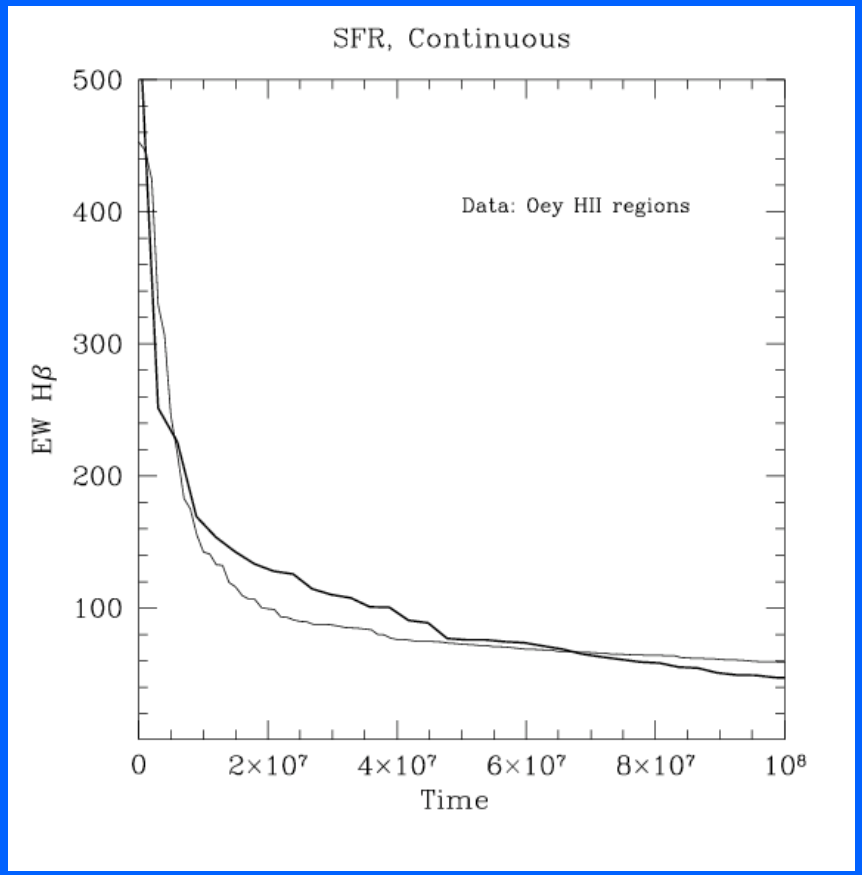
Continuous SF (UCM)



Instantaneous SF (Oey's HII regions)



Continuous SF (Oey's HII regions)



Results are similar for the UCM complete sample of starforming galaxies in the nearby Universe :

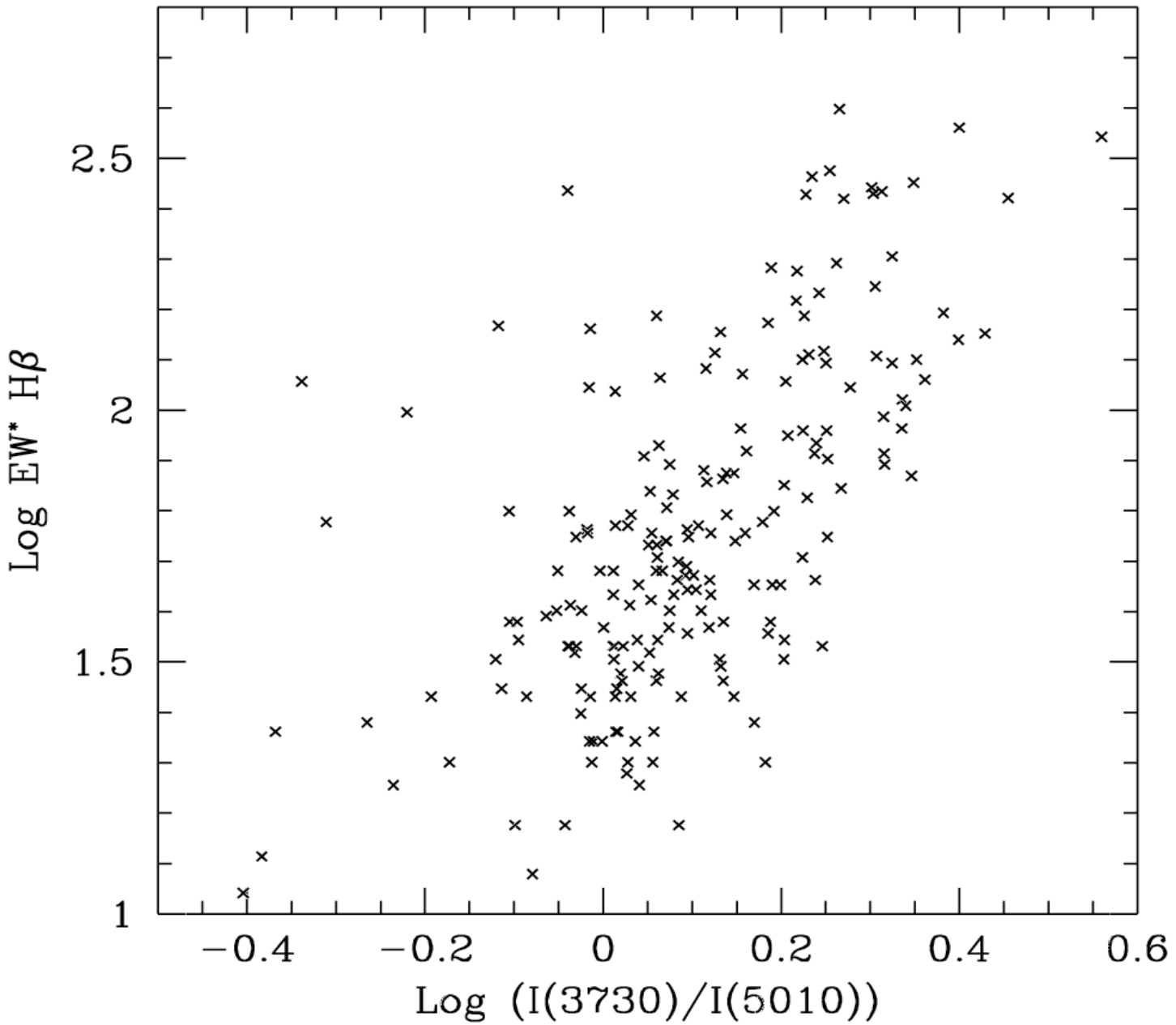
Single Burst model predictions do not fit the shape of the observed evolution of the Equivalent width of H_.

Continuos SFR models give a reasonably good description of the shape of the evolution of the Equivalent width of H_.

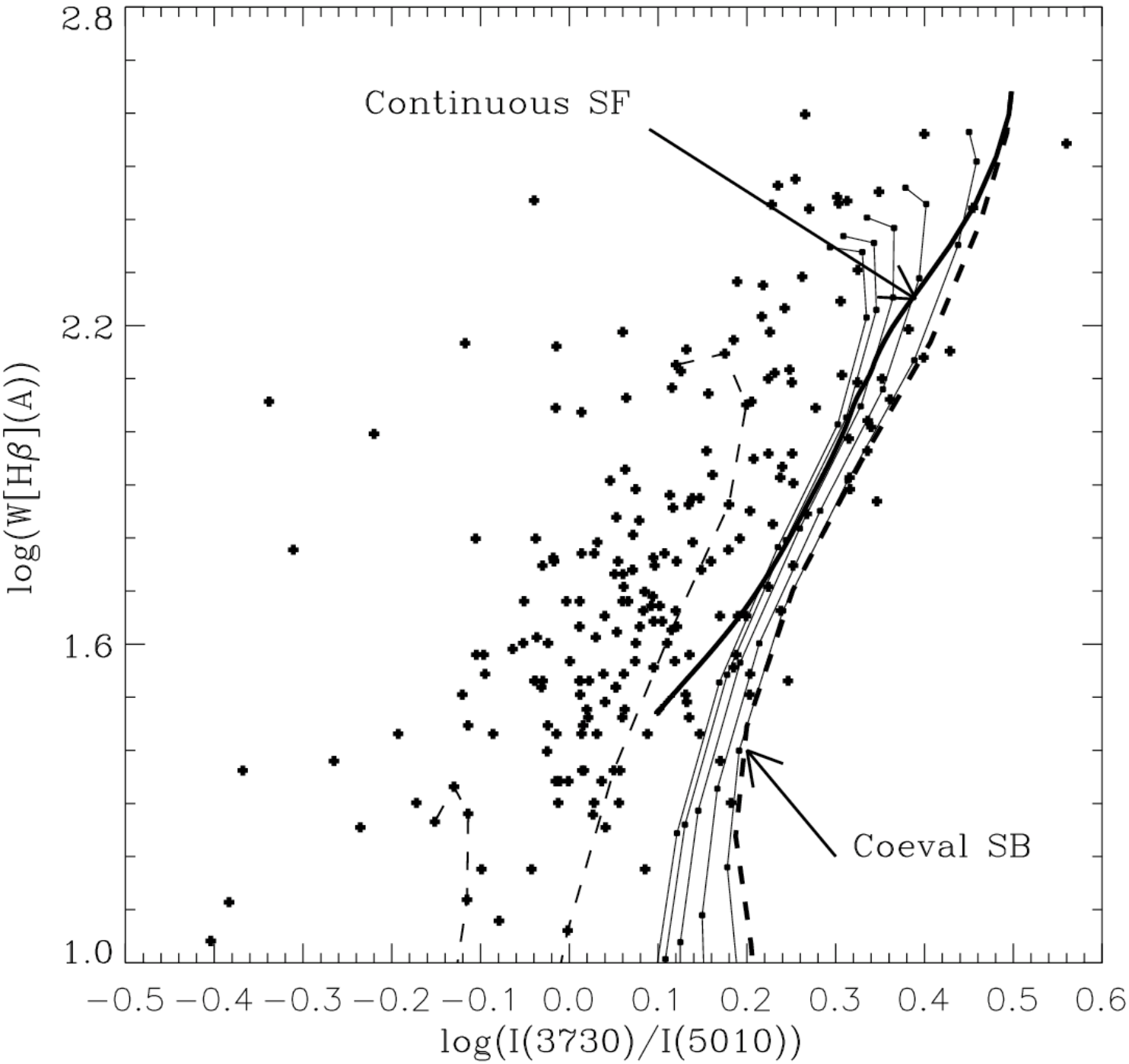
What other parameters can provide information
about the properties of the underlying stellar population?

We have examined the continuum colours and abundances
in HII galaxies as they are sensitive age indicators .

SCHIIG



SCHIIG


Continuous SF
Coeval SB
log(W[Hβ](A))
log(I(3730)/I(5010))
2.8
2.2
1.6
1.0
−0.5 −0.4 −0.3 −0.2 −0.1 0.0 0.1 0.2 0.3 0.4 0.5 0.6

To investigate the scatter and distribution of the observed points in the Colour vs Equivalent Width of H_ plane, we computed simple models of galaxy evolution with multiple bursts.

We find families of solutions to the left of the single population lines where the reddest systems correspond to the longest delays between bursts.

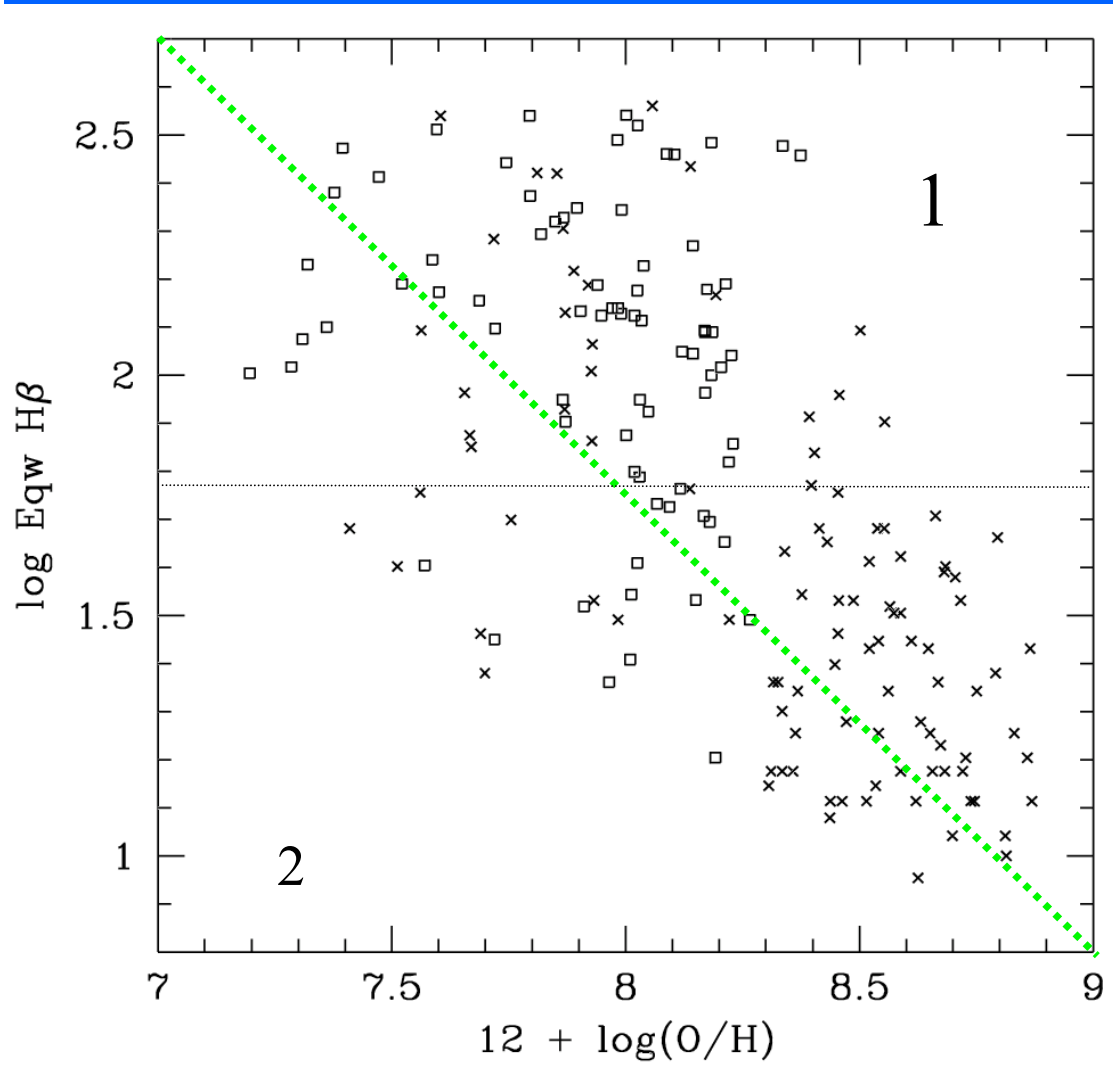
To illustrate this I will show a very simple model having 50 equal strenght burst separated by 20 Myrs.

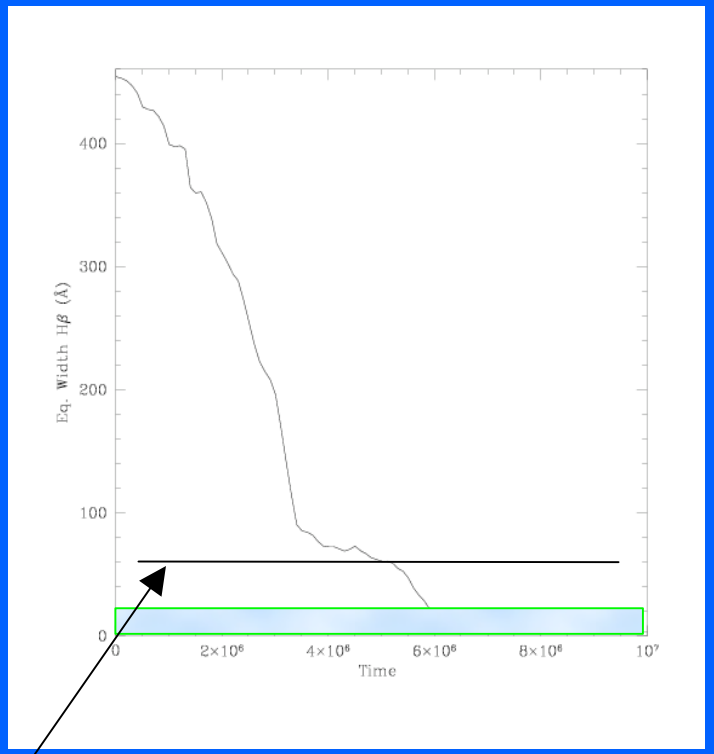
The observed distribution and the scatter of points in the
EqW Hbeta vs Continuum Colour diagram
seems consistent with a population of bursting galaxies.

As the galaxy ages its stellar population becomes redder and more
luminous, and the EqW Hbeta of individual bursts monotonically decreases.

Lets now look at the behaviour of the metallicity in HII galaxies.

Compilation of best determinations of O/H shows a clear relation with EqW HBeta albeit with subtantial scatter.

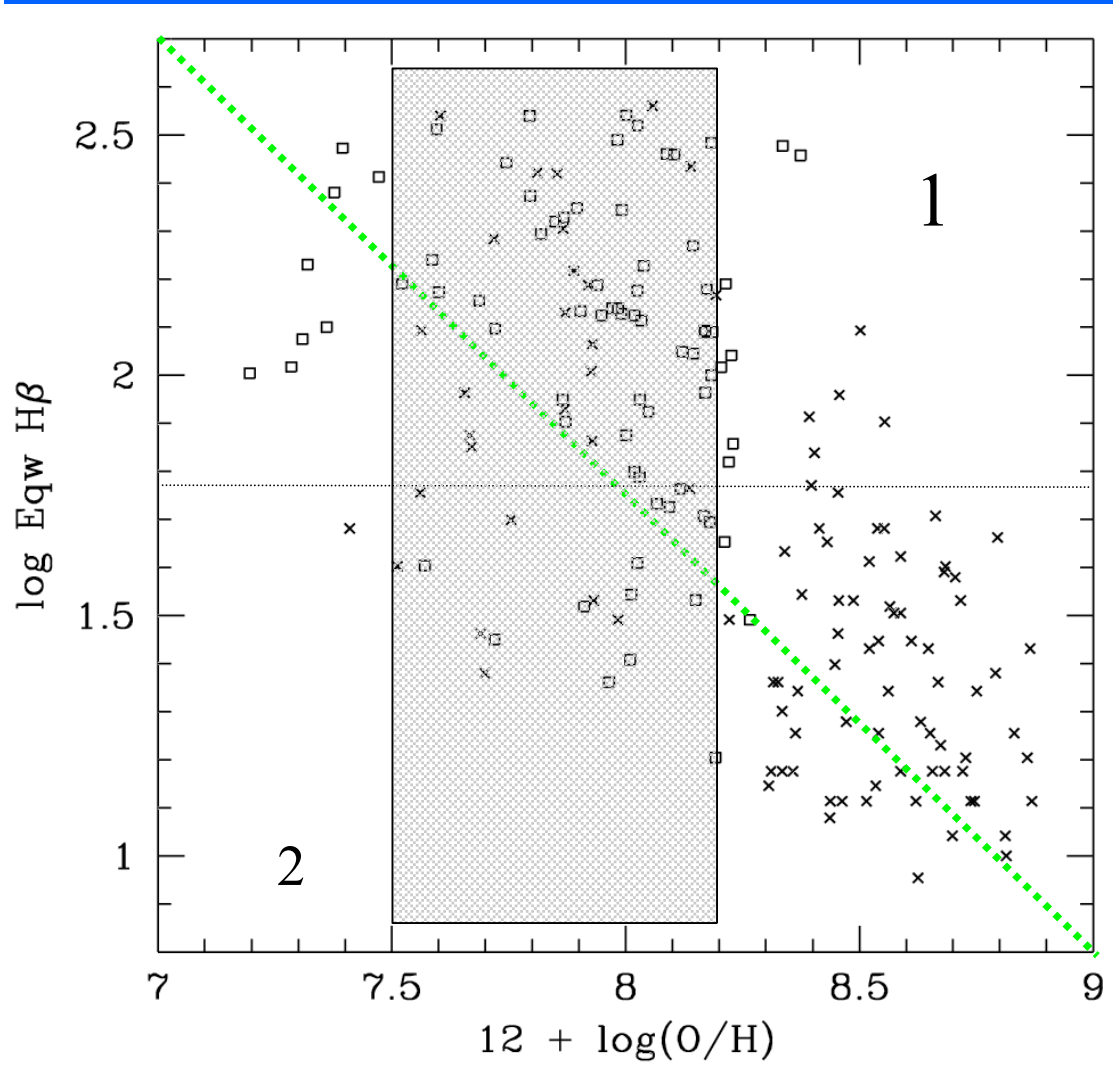


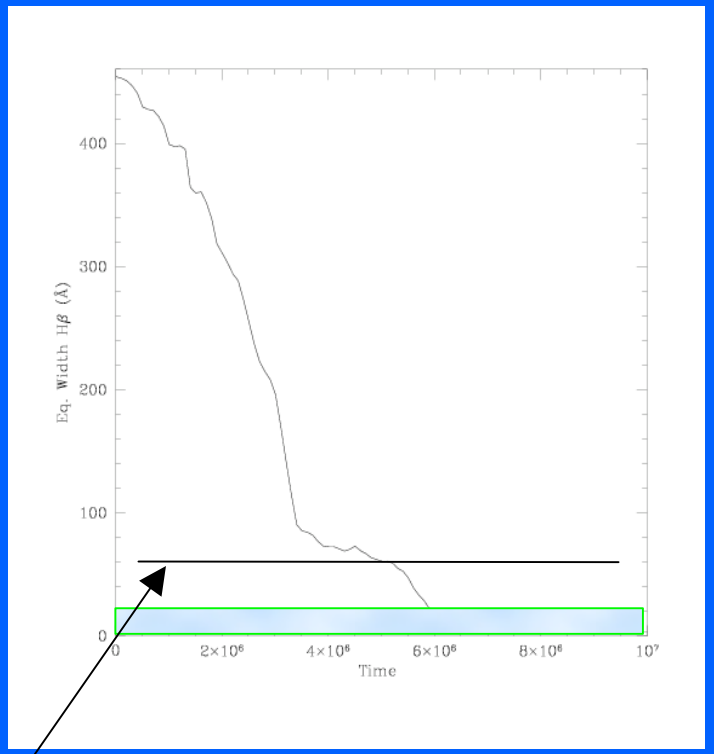


60Å

RESTRICTED METALLICITY RANGE:

$7.5 < 12 + \log(O/H) < 8.2$

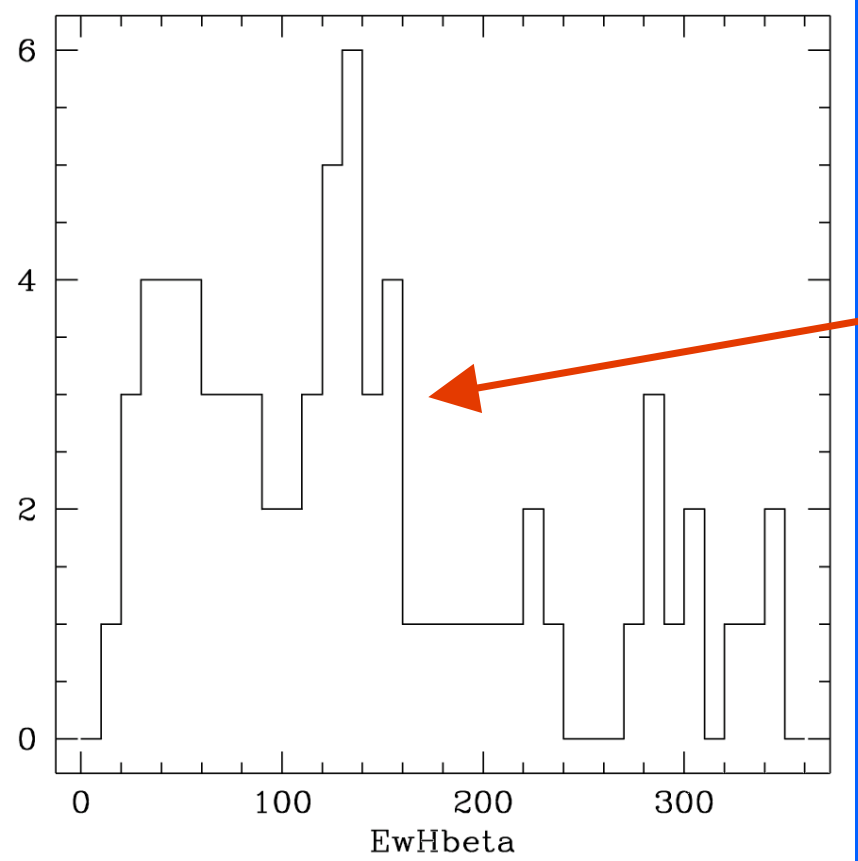




60Å

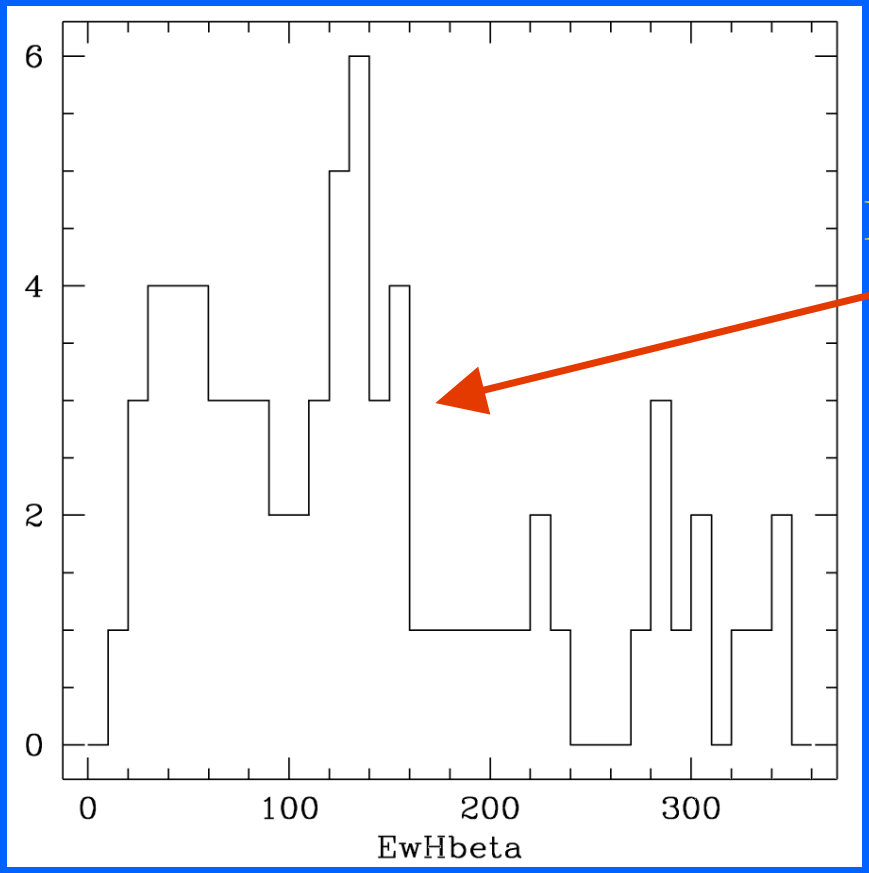
The equivalent width distribution for the RESTRICTED METALLICITY RANGE:

7.5 <12 +Log (O/H) < 8.2

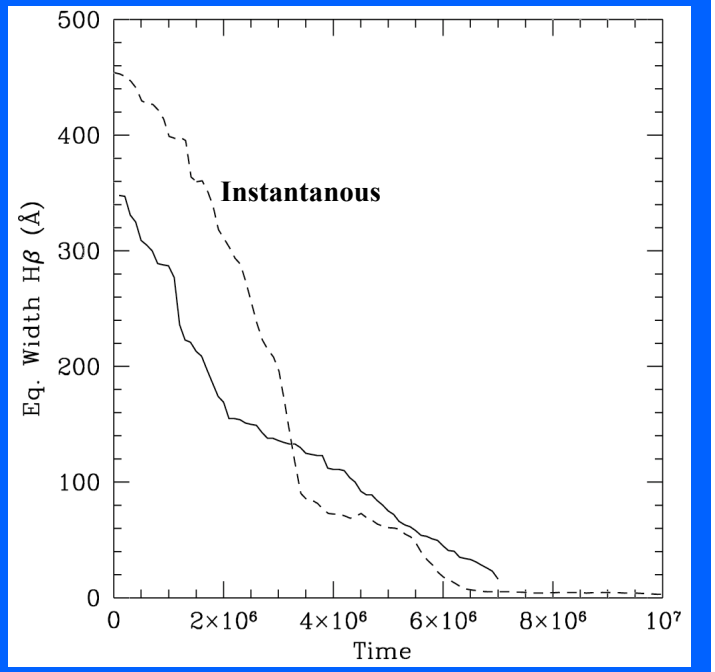


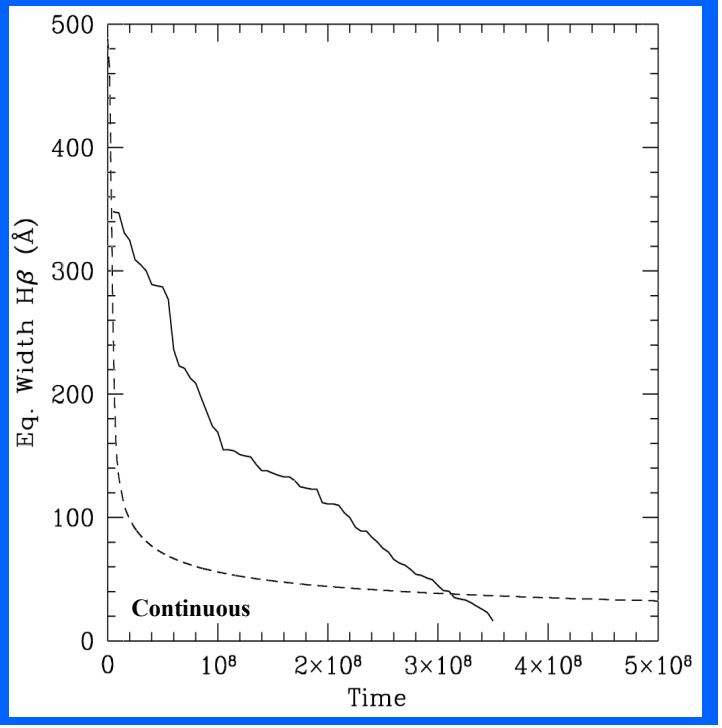
Inversion

RESTRICTED METALLICITY RANGE
7.5 <12 +Log (O/H) < 8.2



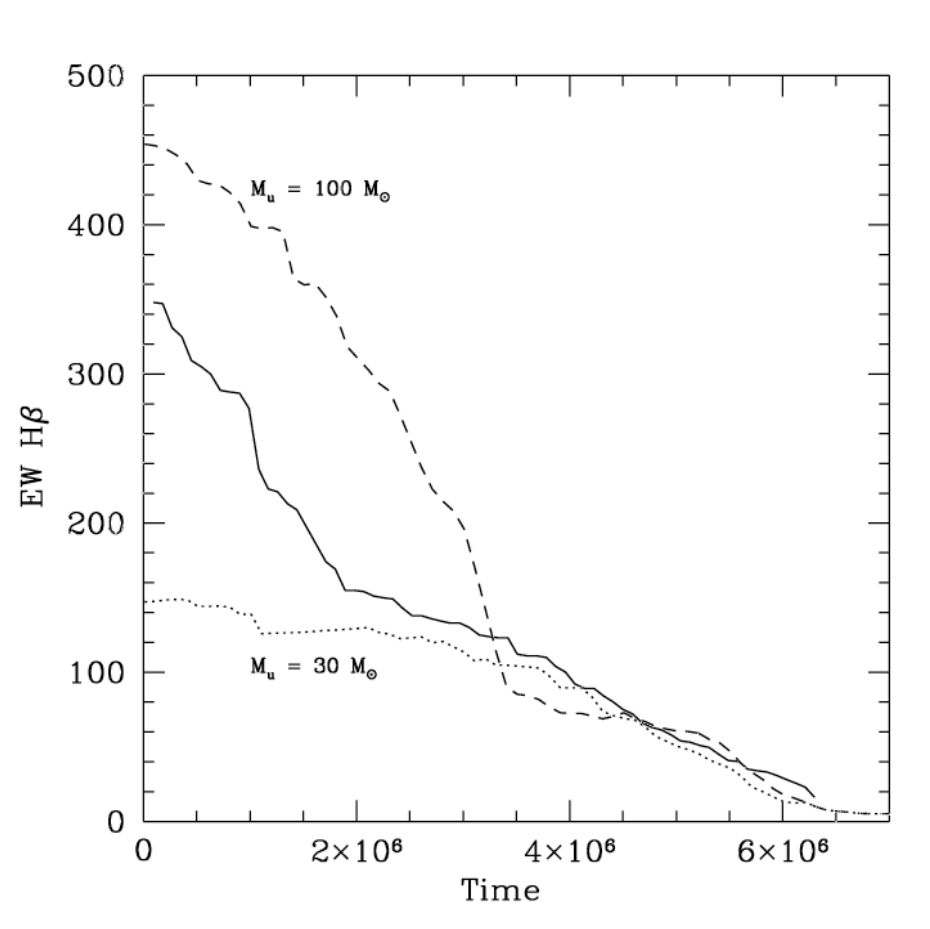
Inversion





RESTRICTED METALLICITY RANGE

$7.5 < 12 + \mathrm{Log}\,(O/H) < 8.2$

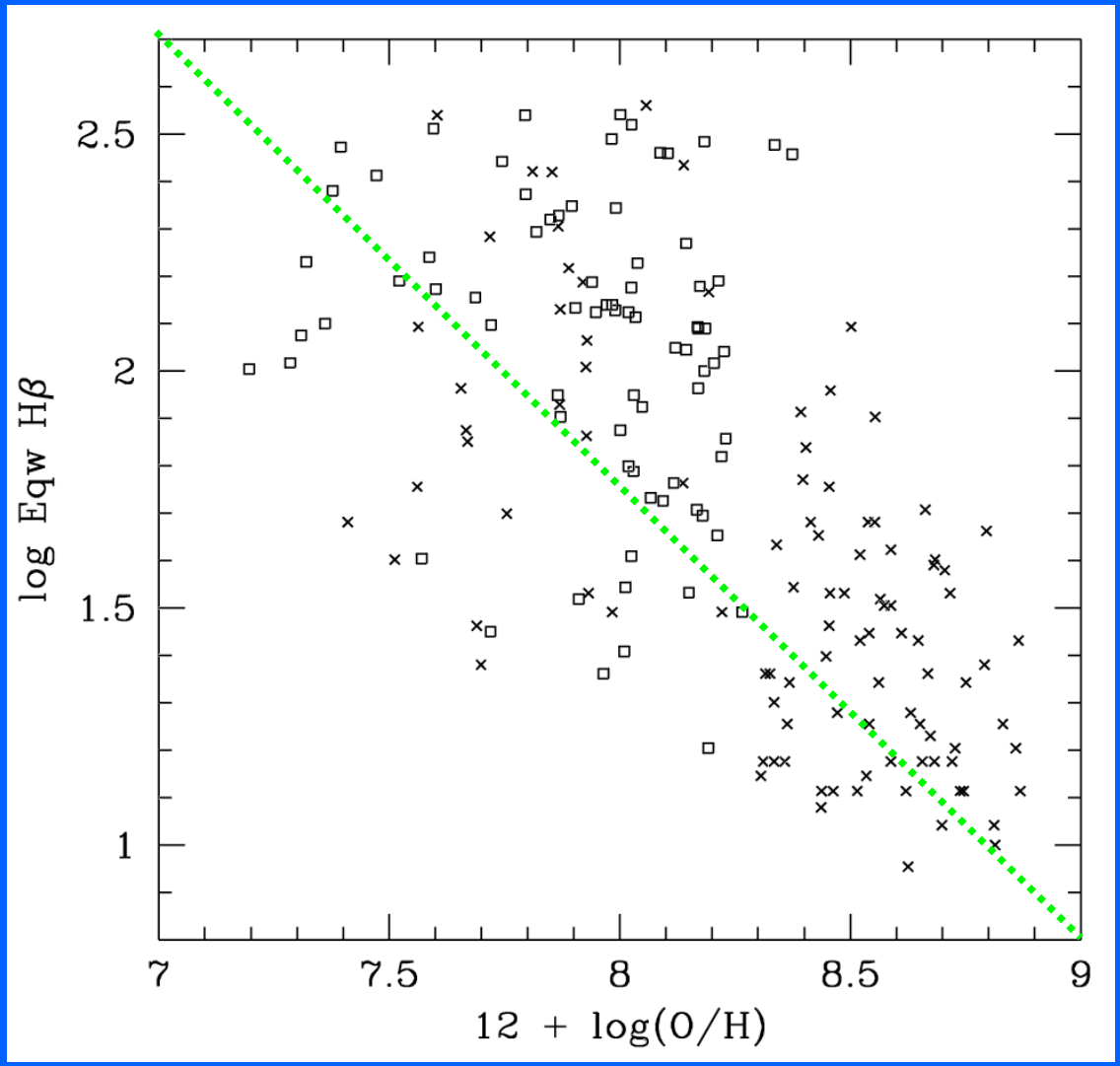


The general shape of the instantaneous law is recovered for the restricted metallicity range sub-sample.

The inversion result lies between the predictions for the instantaneous SF for a Salpeter IMF with upper mass limits of 100 and 30 Solar Masses.

Two time scales

Few Million years



Gigayears

The analysis of large samples will provide new views into old problems.
New semi-supervised methods of analysis are very promising tools.

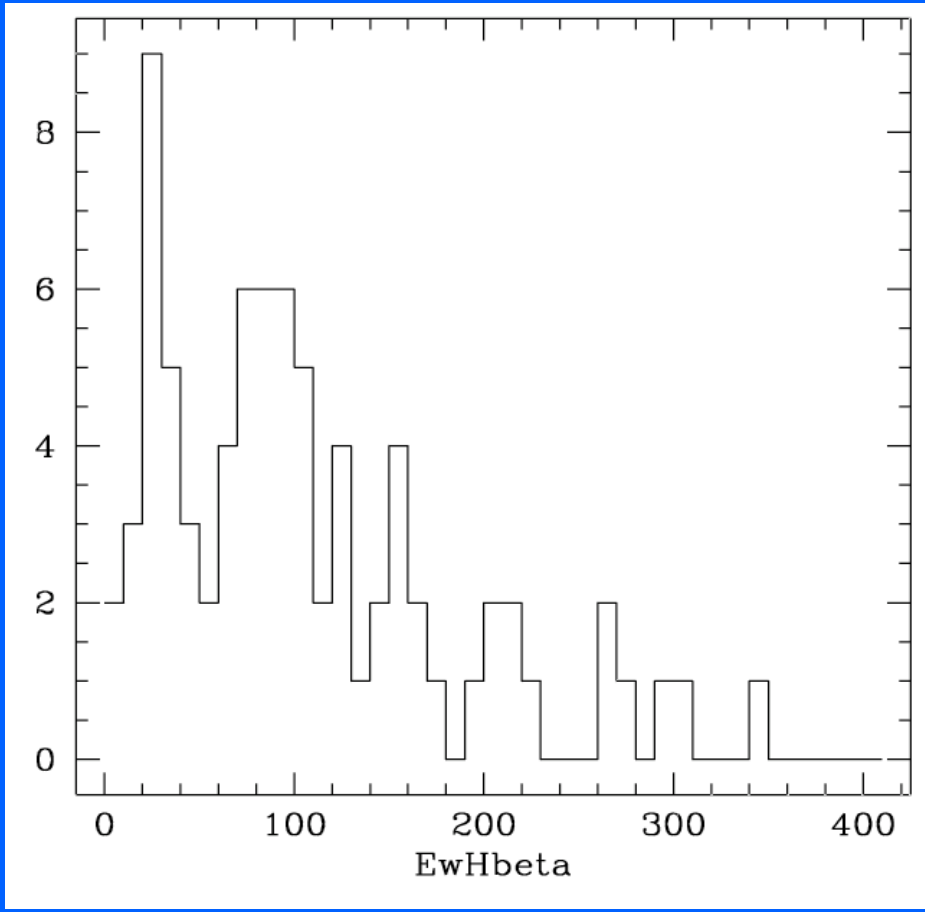
We have shown that the HII galaxies emission line spectral evolution
is not that of a coeval burst.

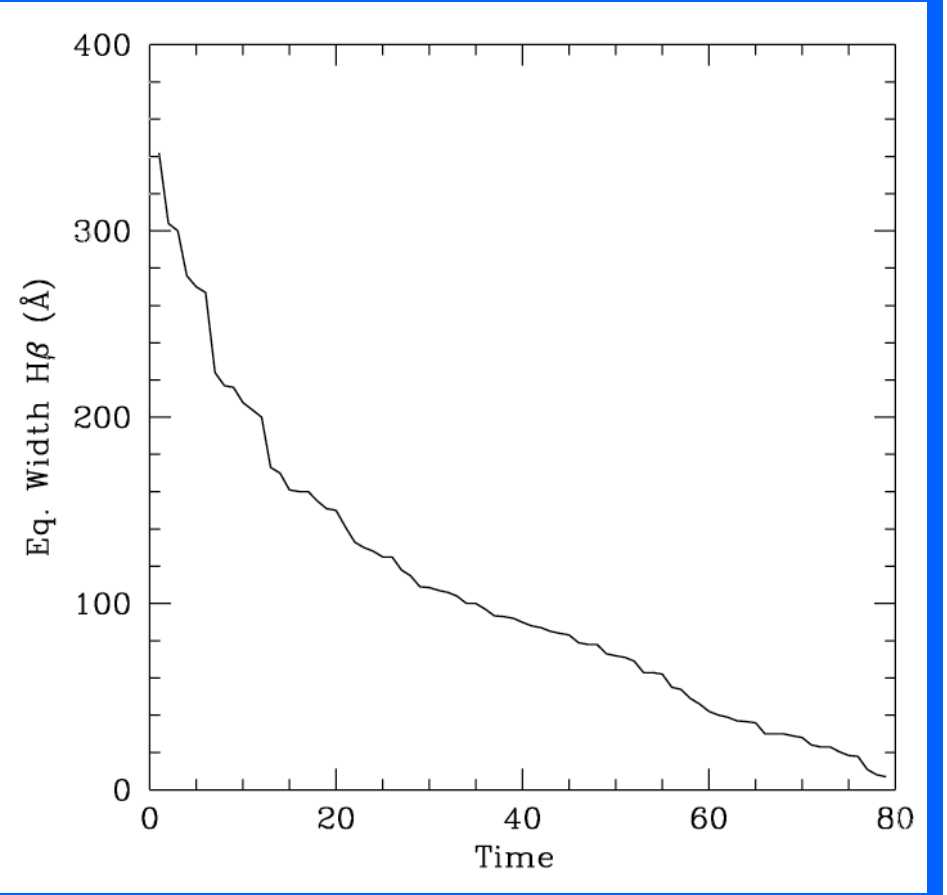
Our inversion method suggests that globally HII Galaxies have a star formation history that is better described by a constant star formation model.

The simplest interpretation is that while the observed emission lines corresponds to the present burst, the underlying continuum contains the whole history of SF of the HII galaxy.

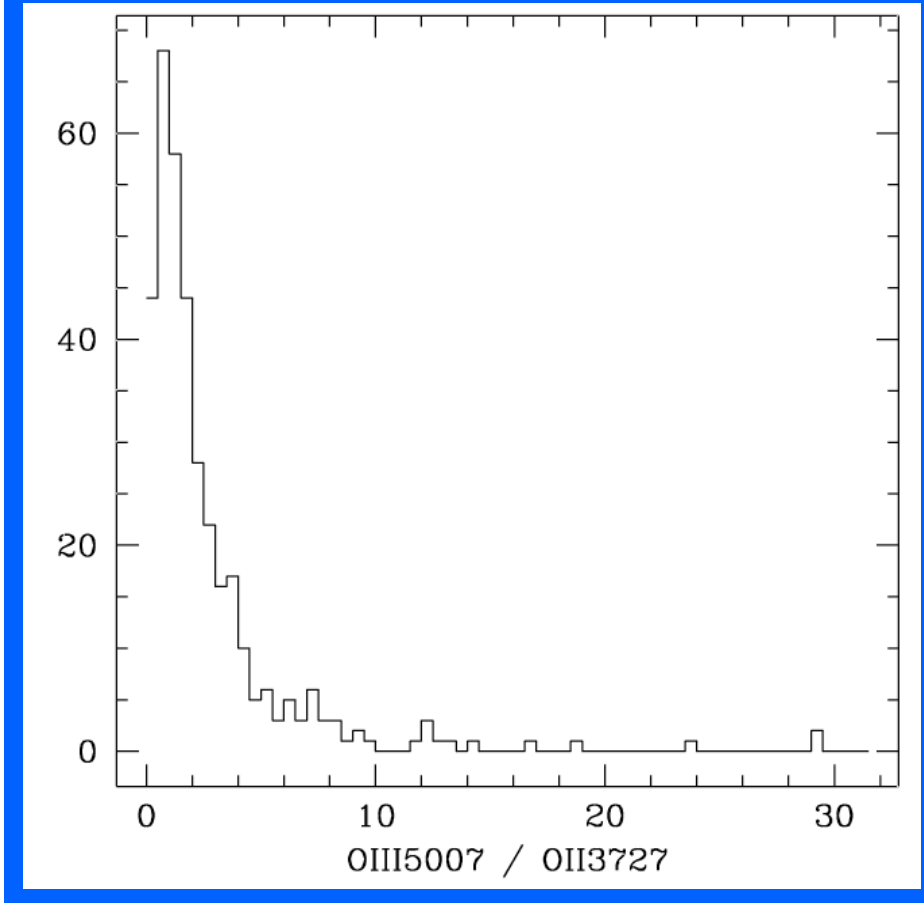
Even though HII Galaxies are selected due to their strong emission lines,
they are not truly young galaxies. Most of them have undergone substantial
SF previous to the present burst probably during the previous
100 - 1000 Myr.

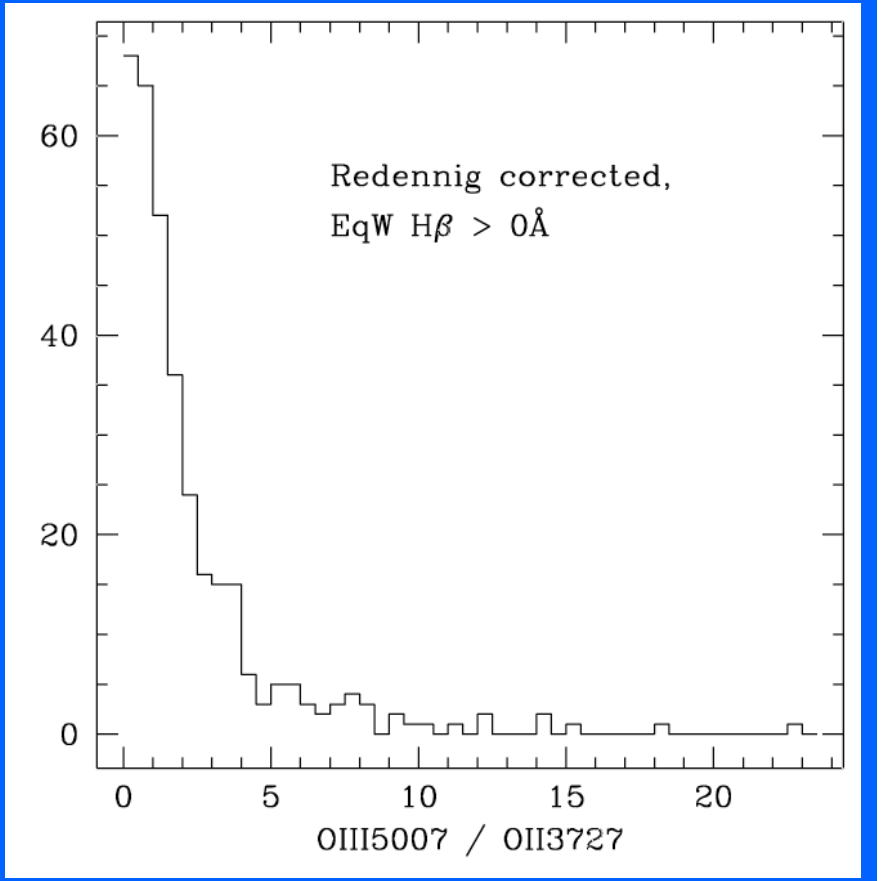
W-R Galaxies


0
2
4
6
8
0
100
200
300
400
EwHbeta

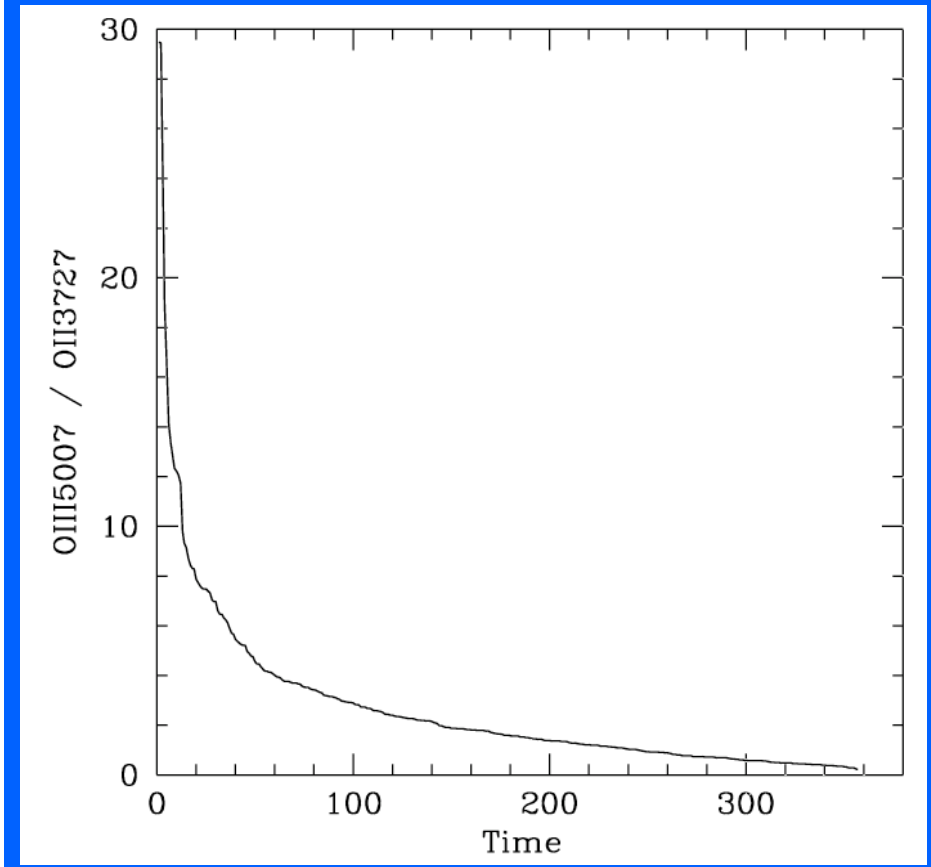

0
100
200
300
400
Eq. Width Hβ (Å)
0
20
40
60
80
Time

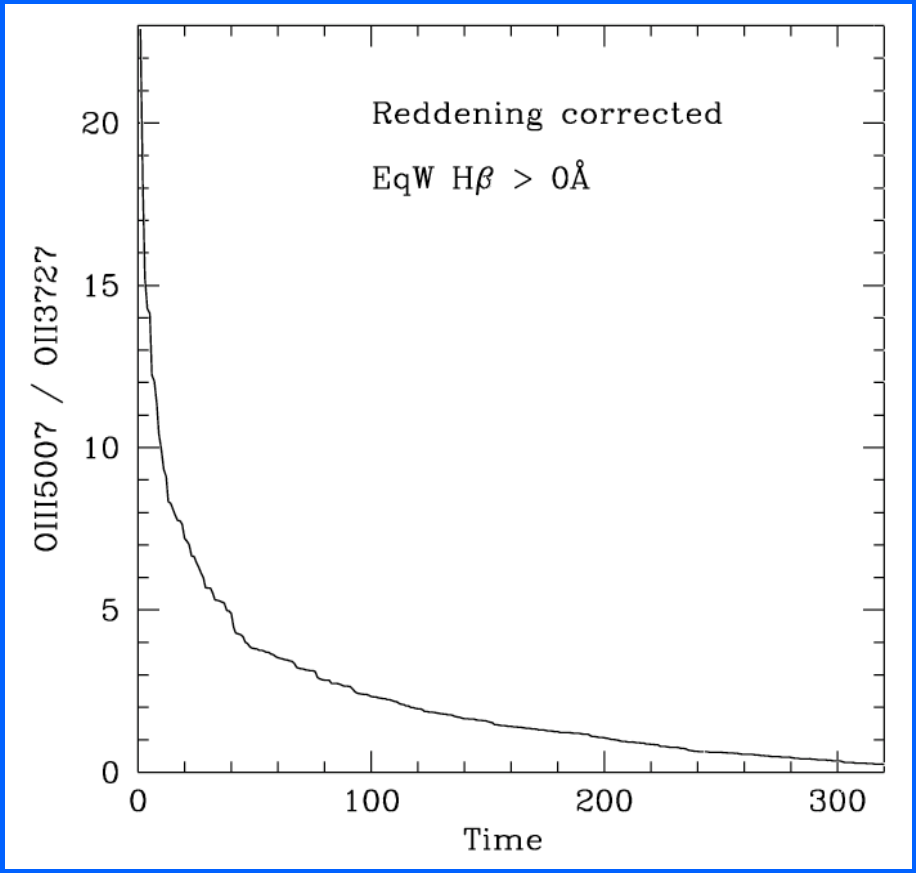
Ionization parameter distribution

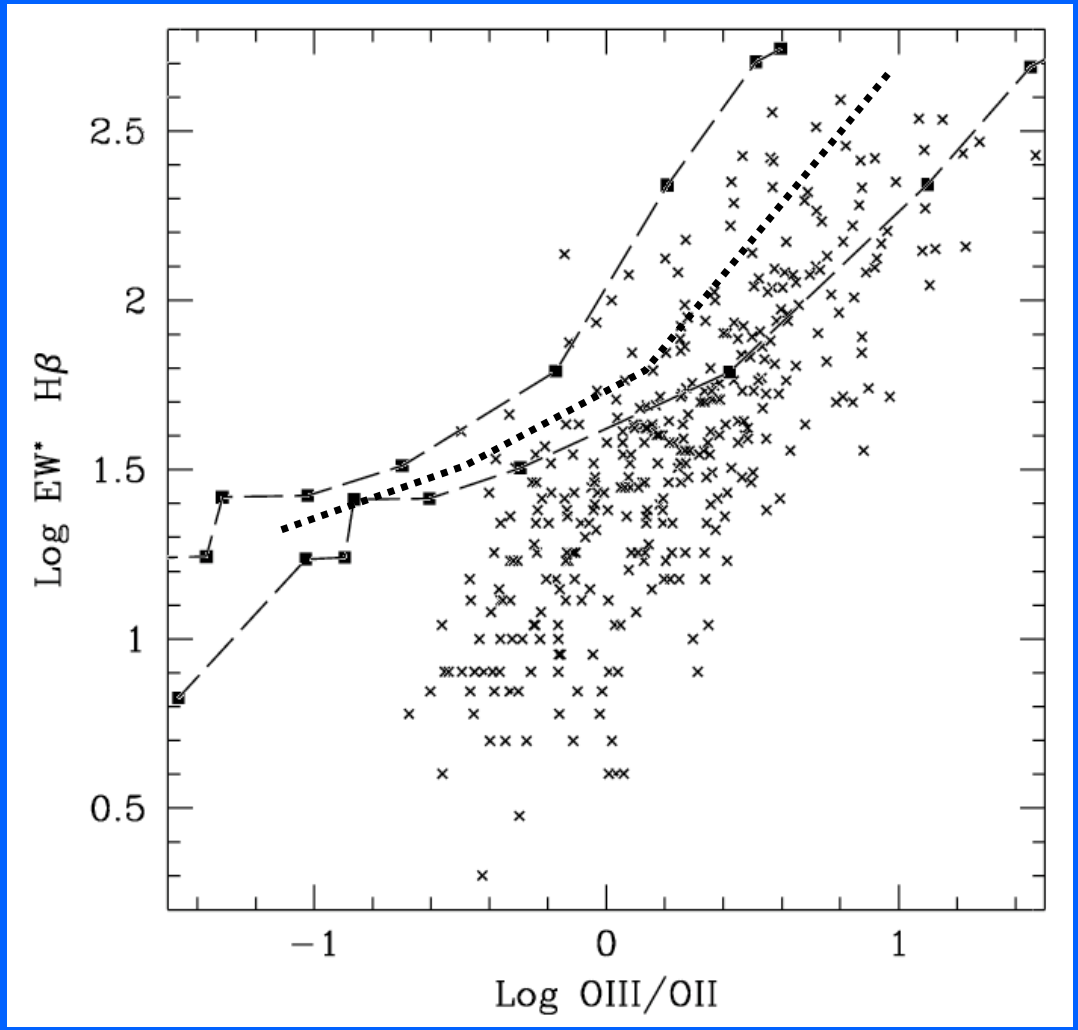




The inverted [OIII]/[OII] probability density distribution showing an estimate of the “Ionization Parameter” evolution






2.5
2
1.5
1
0.5
Log EW* Hβ
−1
0
1
Log OIII/OII

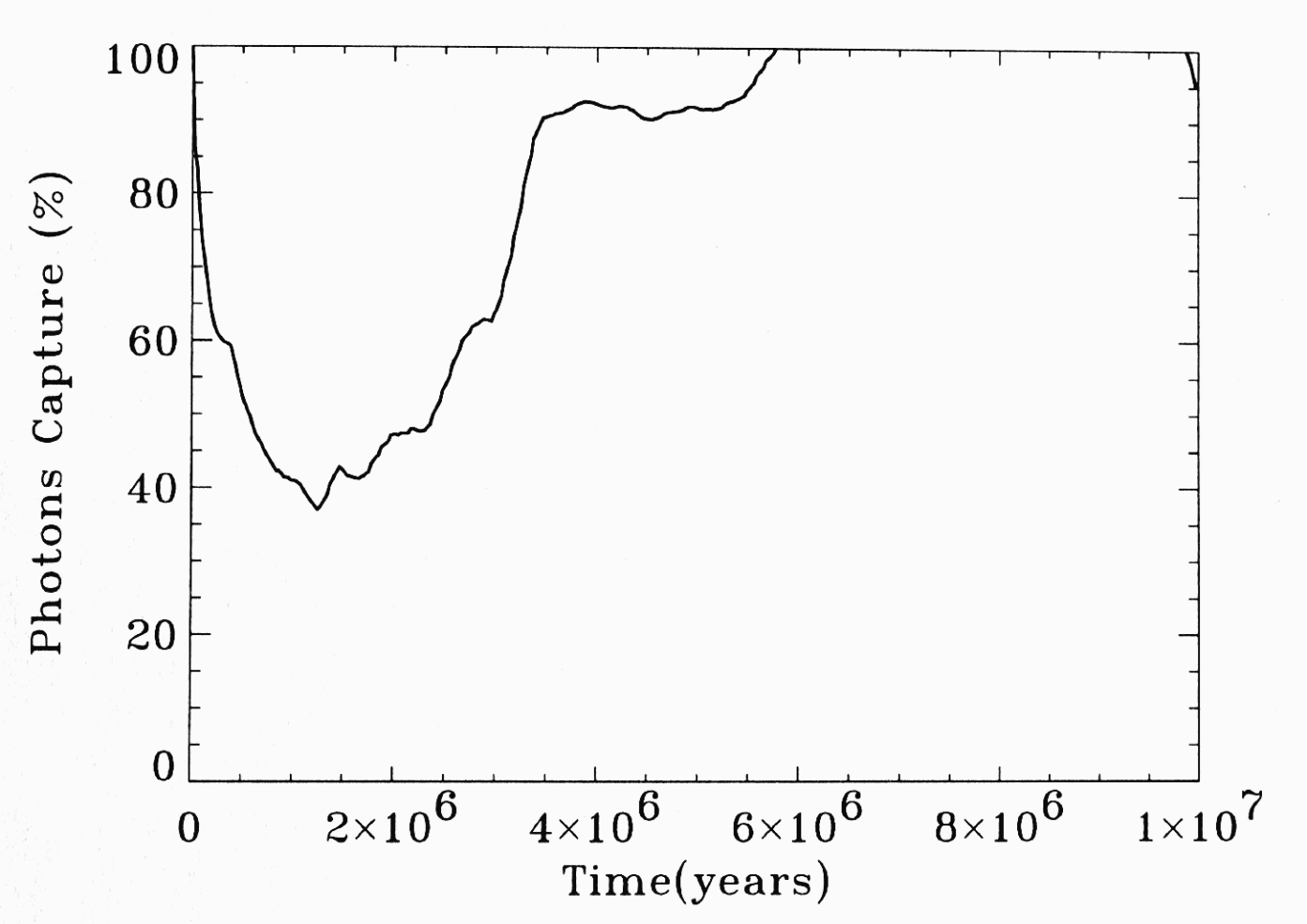
Results are similar for Oey's sample of HII regions
in nearby galaxies:

Single Burst model predictions do not fit the shape of the observed evolution of the Equivalent width of H_.

Continuos SFR models give a reasonably good description
of the shape of the evolution of the Equivalent width of H_.

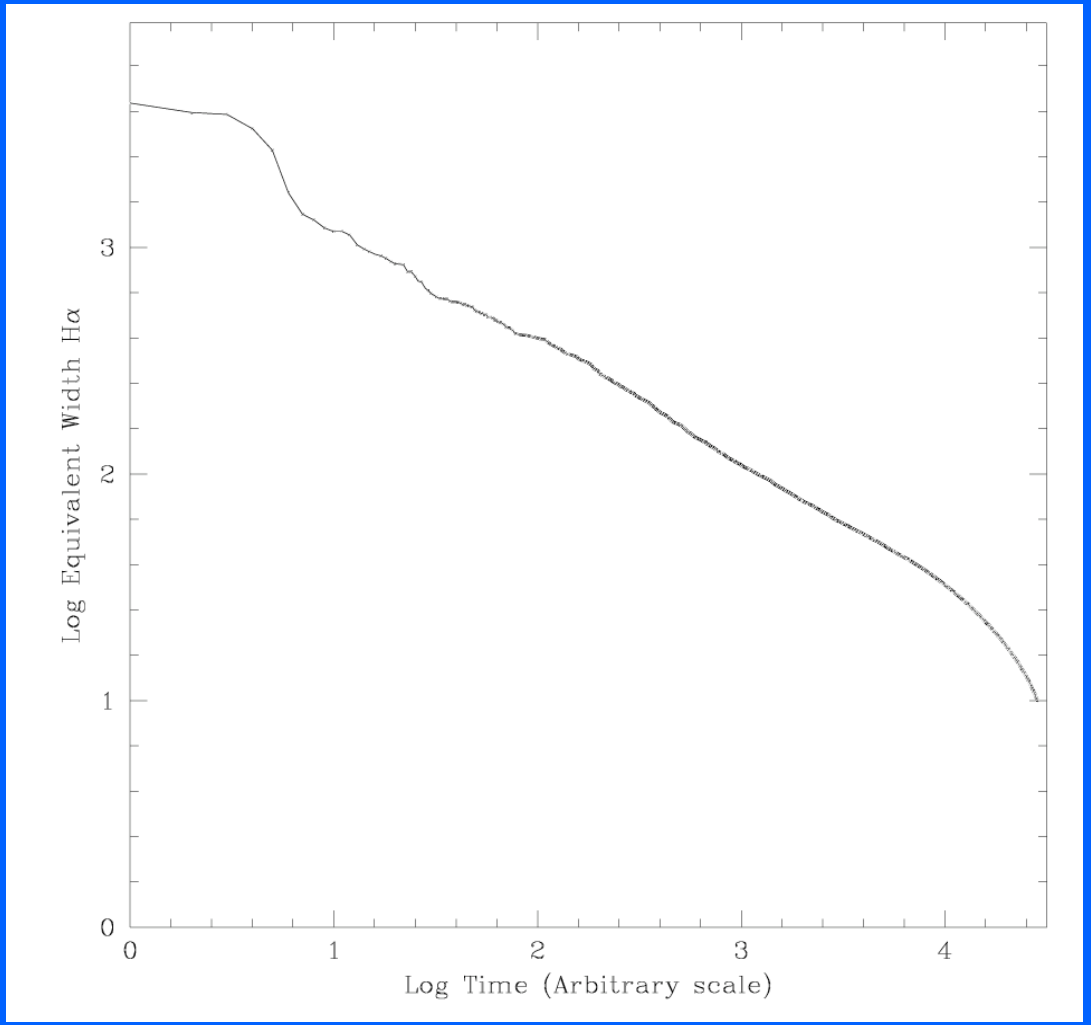
- **What about time dependent effects?**

In principle, a time dependent photon escape can also explain the differences in shape between the instantaneous model and the observations.

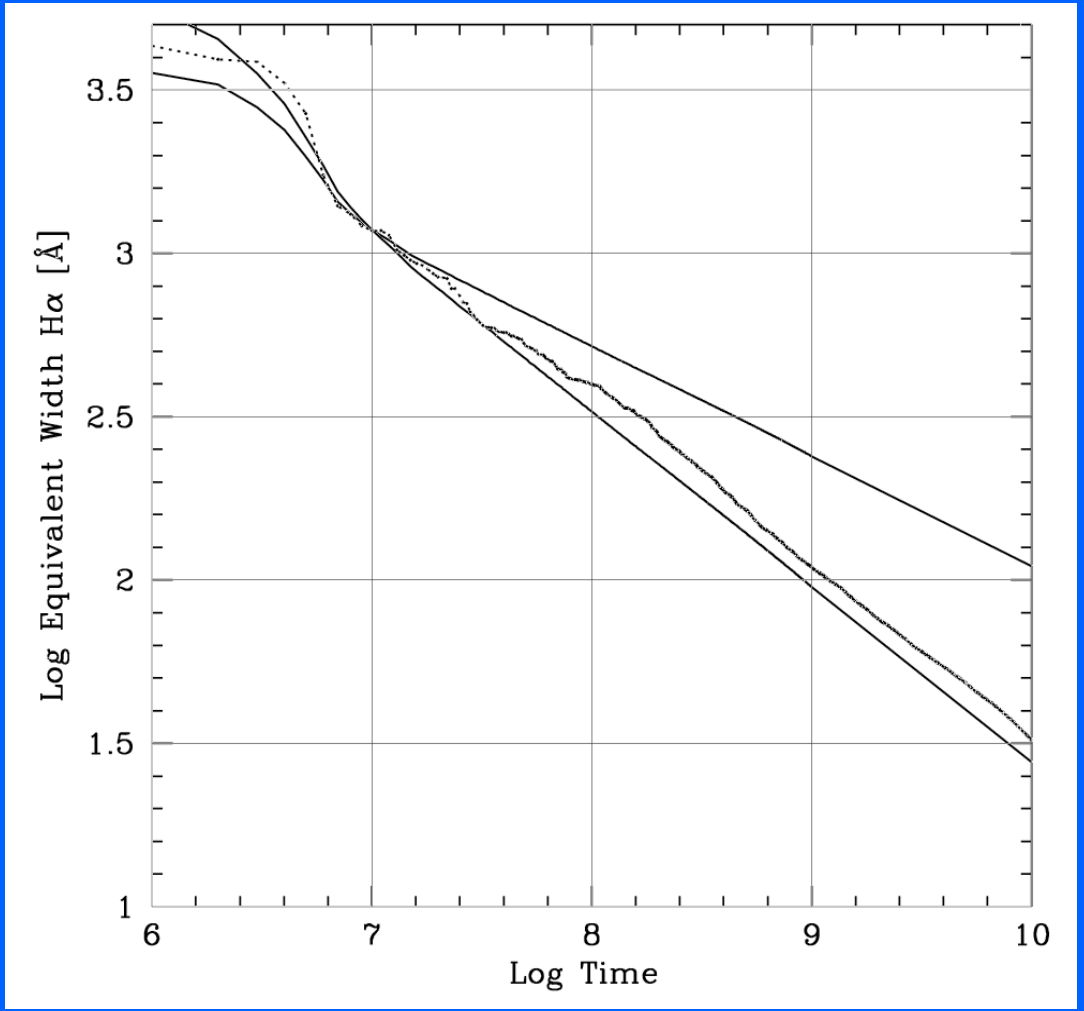


Inverted distribution from SLOANE EDR

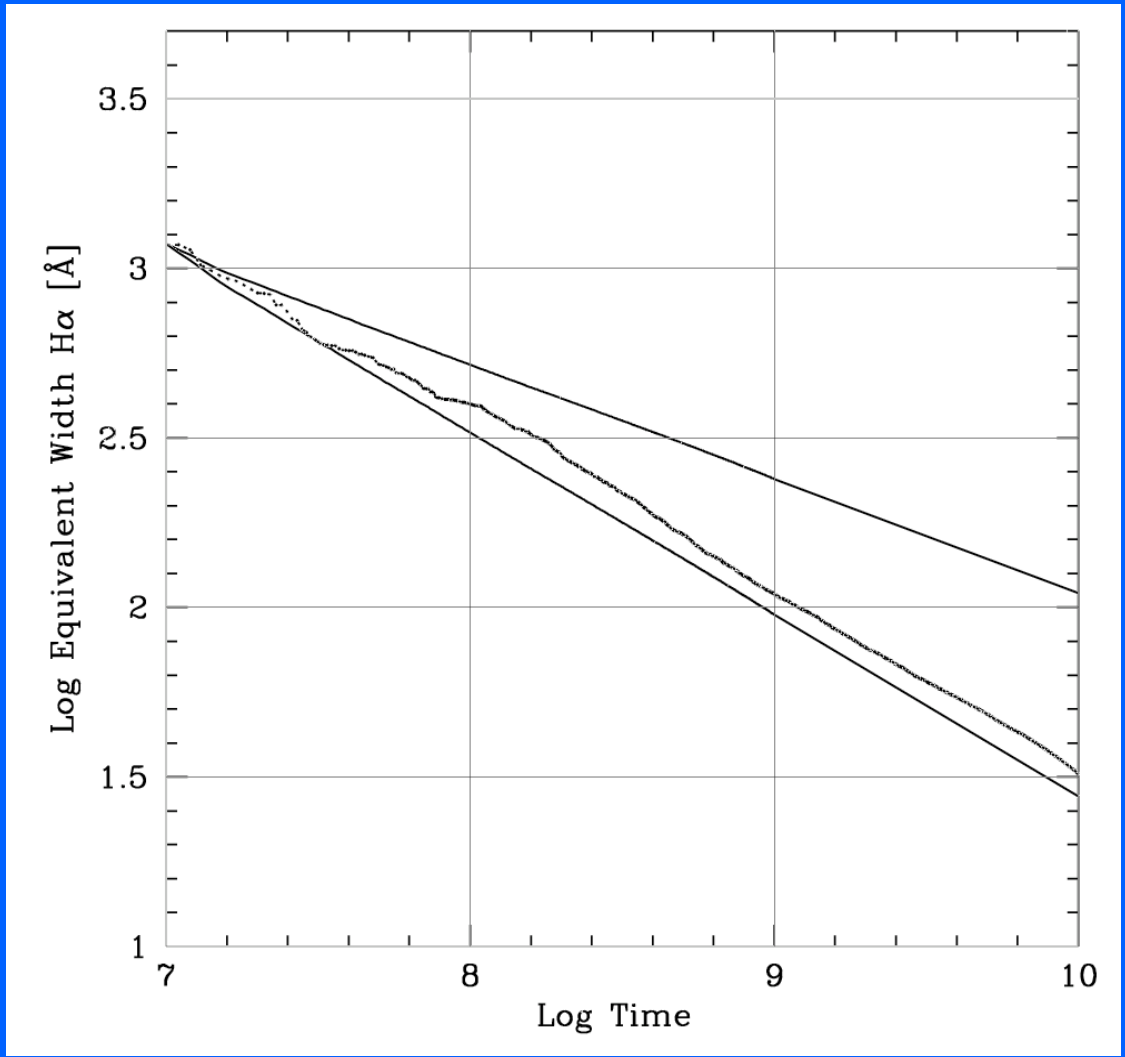
PROVISIONAL



Inverted distribution from SLOANE EDR compared with models computed with SB99 for constant SFR and linearly diminishing SFR



Inverted distribution from SLOANE EDR compared with models computed with SB99 for constant SFR and linearly diminishing SFR

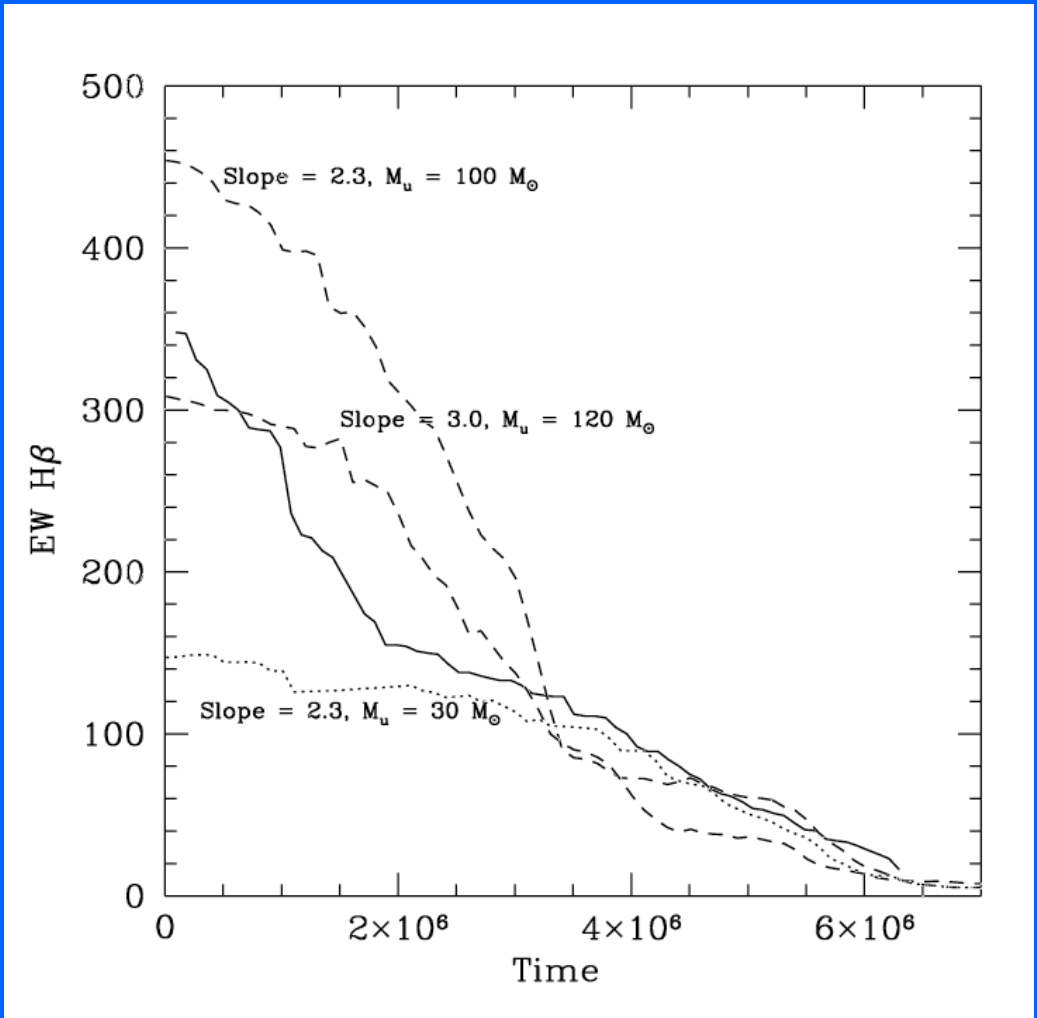


RESTRICTED METALLICITY RANGE

$7.5 < 12 + \mathrm{Log}\,(O/H) < 8.2$

The general shape of the instantaneous law is recovered for the restricted metallicity range sub-sample.

The inversion result lies between the predictions for the instantaneous SF for a Salpeter IMF with upper mass limits of 100 and 30 Solar Masses.



YMC in Type 1 Seyferts

These nuclear YMC in Seyferts are very luminous, with luminosities up to 10^11 Solar Luminosities

Their study is bound to bring new information and insights into bulge Formation and evolution and the relation between VSF and AGN activity.

