Precision cosmology with young massive SSC and the Universality of the IMF.

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KICC Workshop 2017

H II Galaxies = The youngest and more massive SSC

HII galaxies are compact massive burst of star formation in dwarf galaxies.

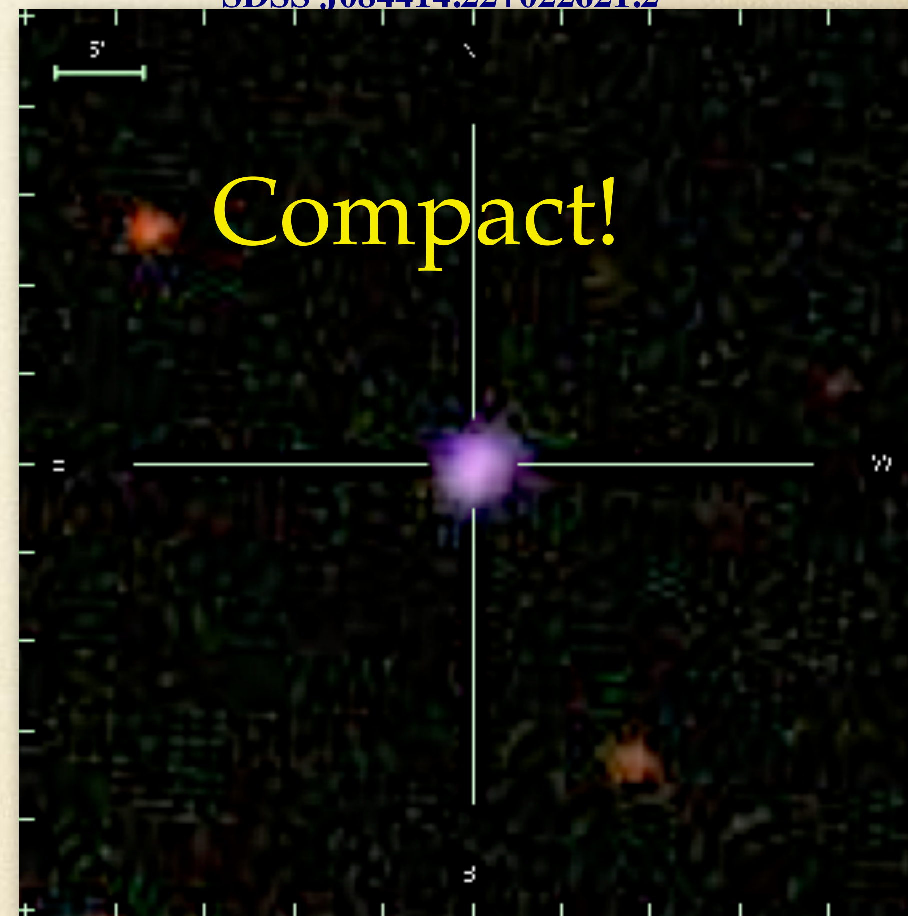
They are selected from spectroscopic surveys for their strong narrow emission lines with equivalent width, **EW(Hβ) > 50Å or EW(Hα) > 200Å and small size.**

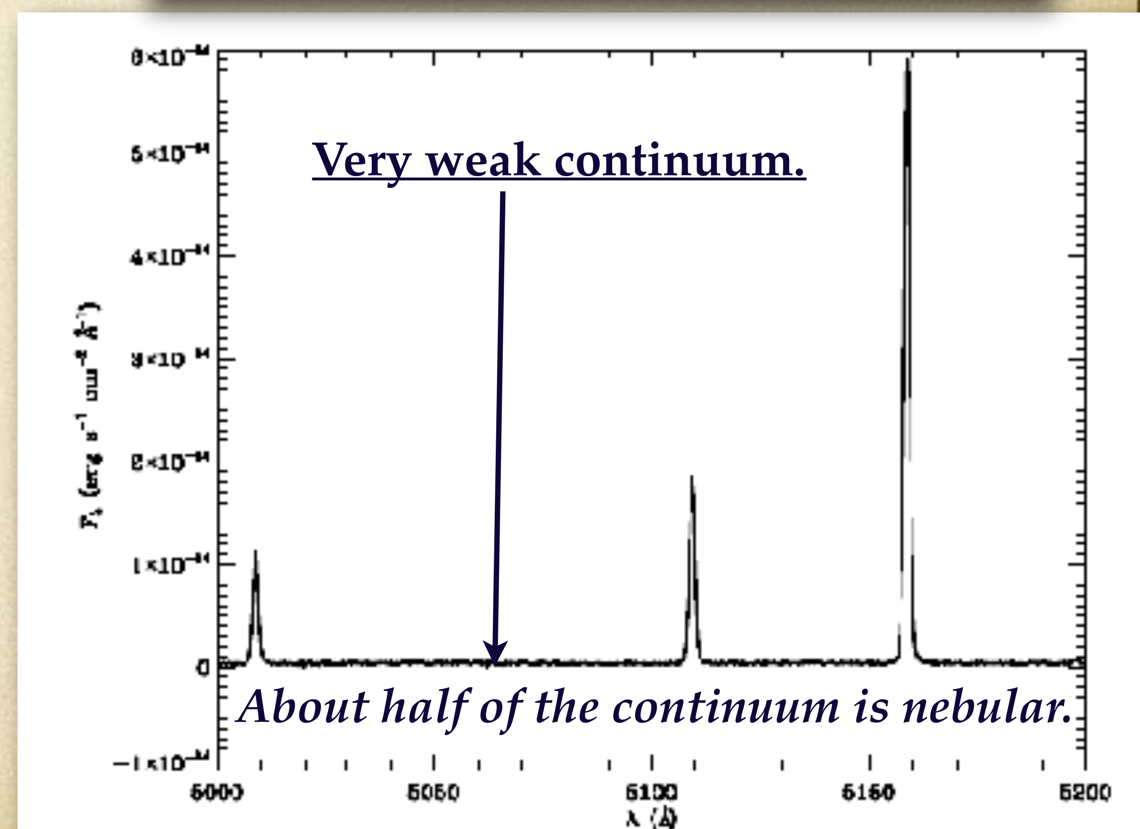
The luminosity of HII galaxies is almost completely dominated by the young burst.

The parent galaxy is difficult to detect.

<u>**The observed properties are those of a very young Super Stellar Cluster (SSC) with almost no contamination from the parent galaxy.**</u>

SDSS J084414.22+022621.2





Evolution of the Eq. width of Hβ in a burst (SB99)

Selecting compact narrow emission line systems with EW of Hβ > 50Å or Hα > 200Å provides a homogeneous sample with:

-An upper limit to its age (~ 5Myr),

-Limited escape of ionising radiation,

-Limited contamination by an older population

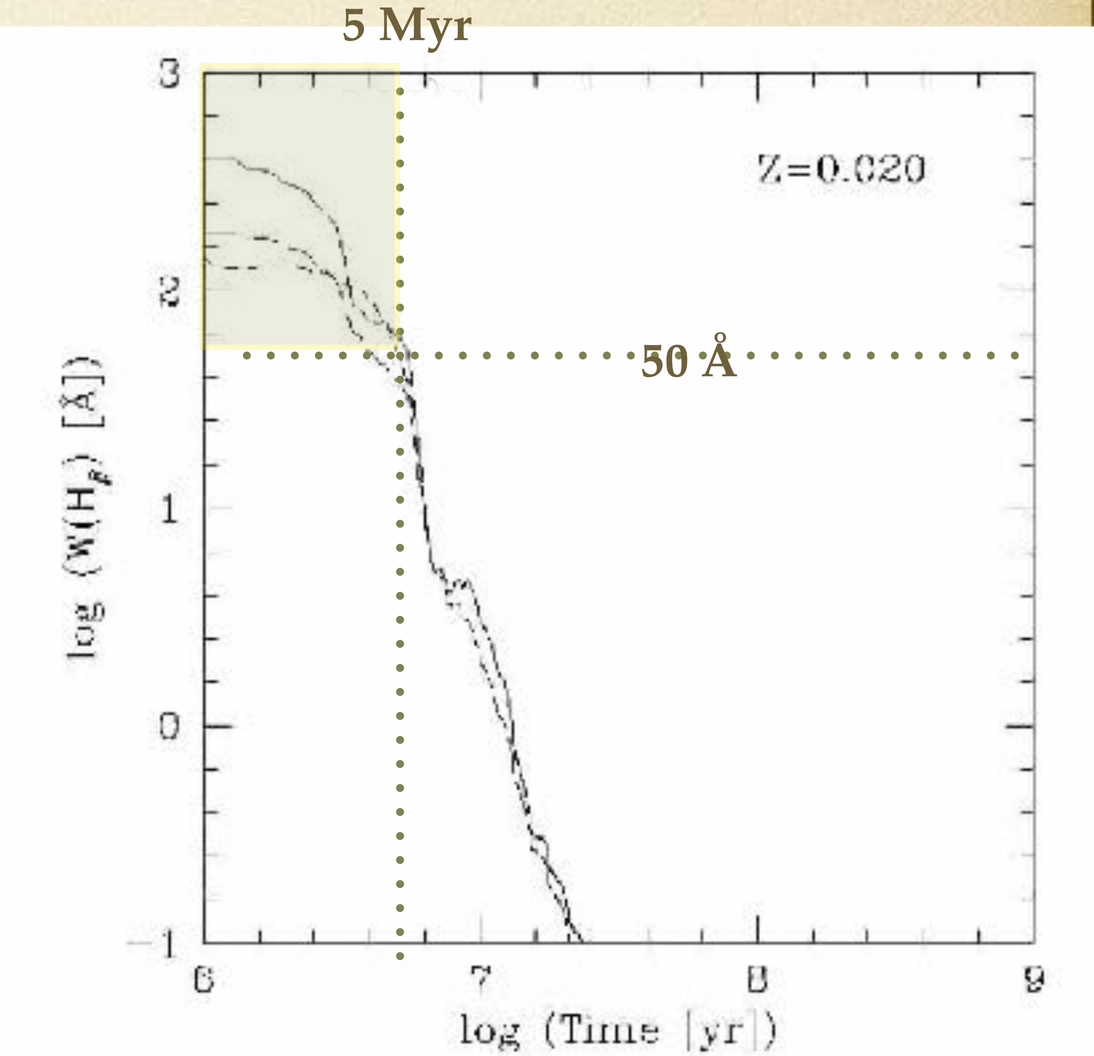
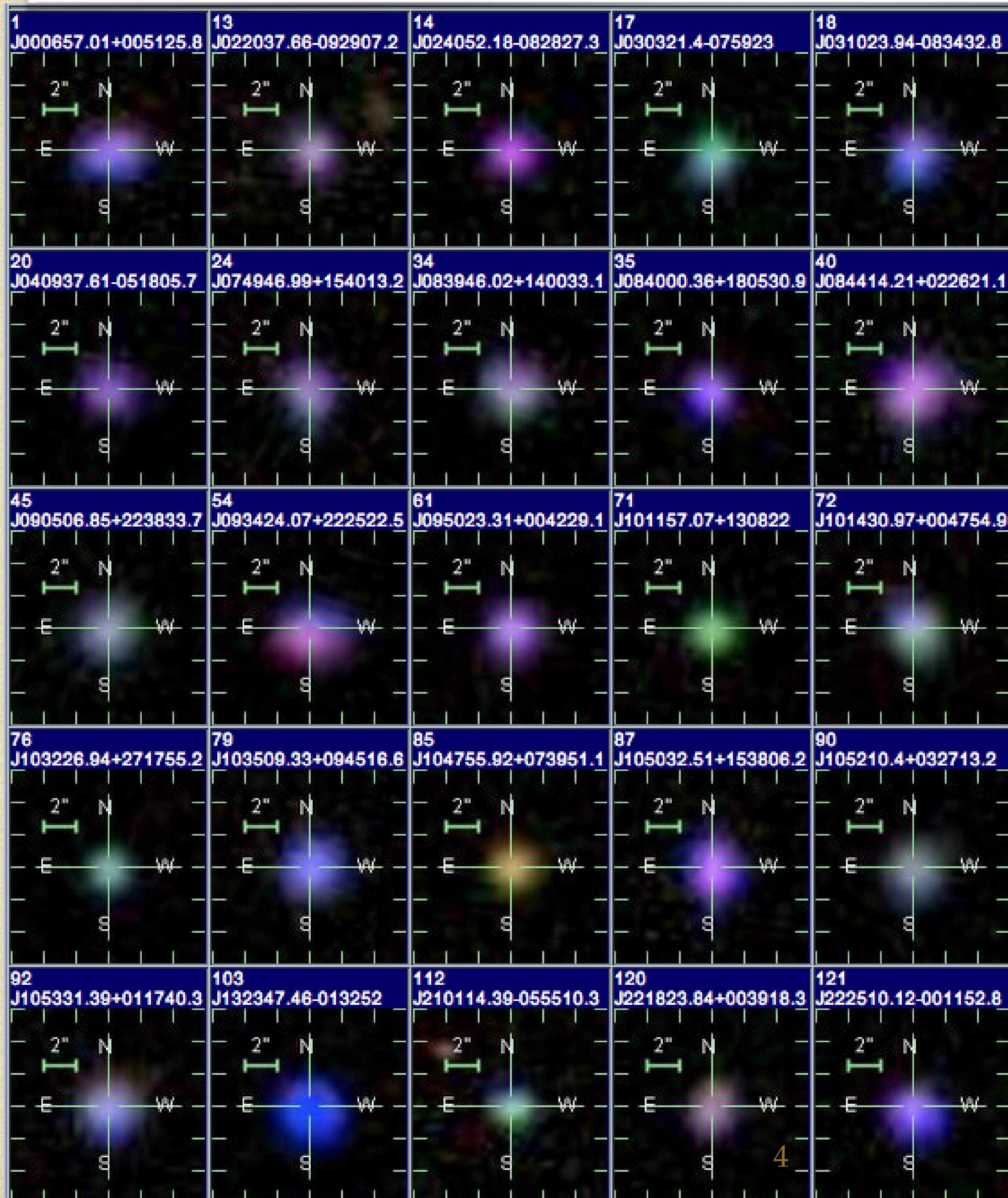


FIG. 85b

FIG. 85.—Hβ equivalent width vs. time. Star formation law: instantaneous; *solid line*, $\alpha = 2.35$, $M_{up} = 100\ M_\odot$; *long-dashed line*, $\alpha = 3.30$, $M_{up} = 100\ M_\odot$; *short-dashed line*, $\alpha = 2.35$, $M_{up} = 30\ M_\odot$; (*a*) $Z = 0.040$; (*b*) $Z = 0.020$; (*c*) $Z = 0.008$; (*d*) $Z = 0.004$; (*e*) $Z = 0.001$.

SDSS Images of H II Galaxies - COMPACT!!



The colour in these SDSS stamp images depends on redshift.

Some are green most are not.

Are BCD HII Galaxies?

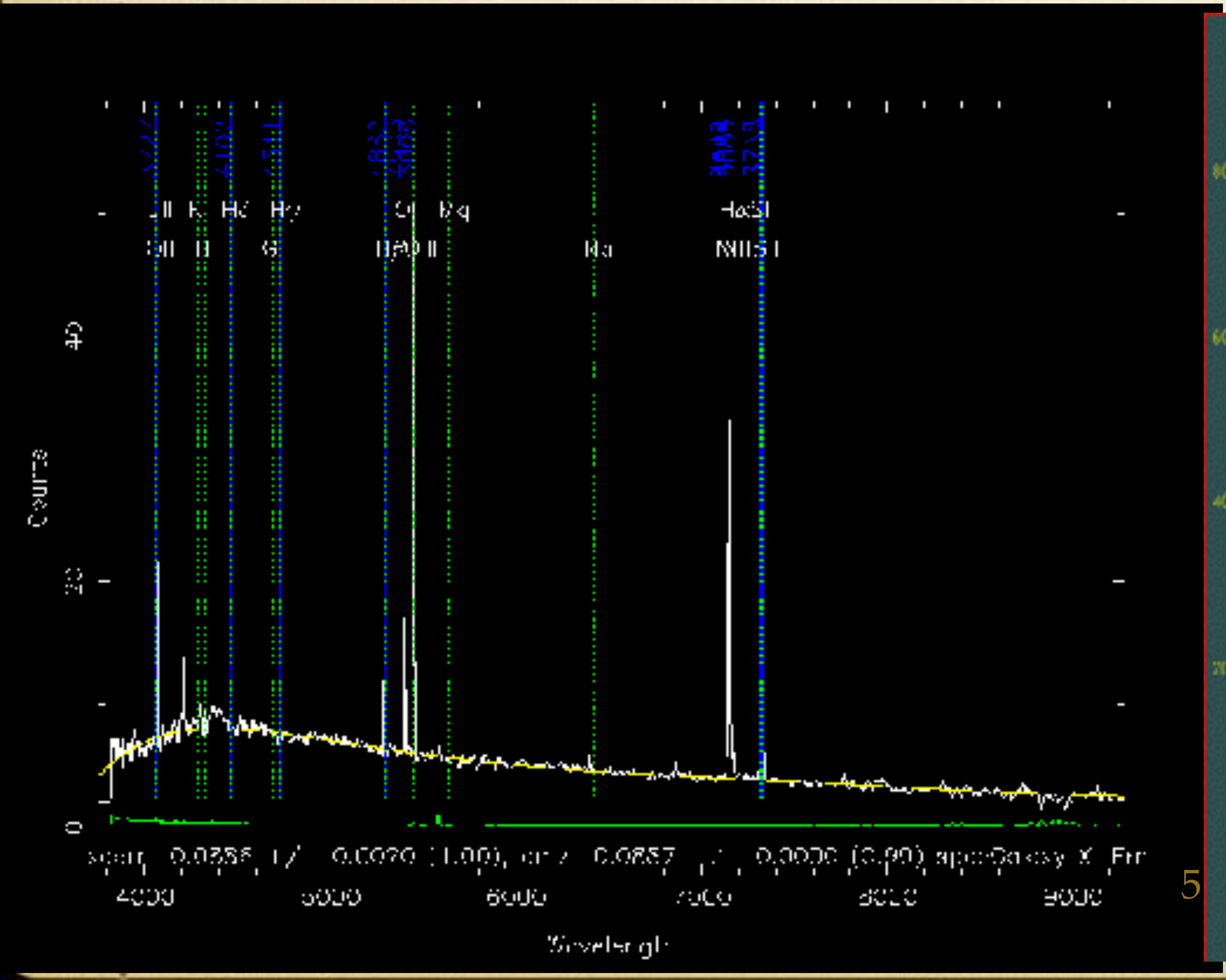
<u>The answer is: generally no.</u>

Blue Compact Dwarf (BCD) were selected by Fred Zwicky by colour and compactness. This selection provides samples of galaxies with a young population but in contrast with HII galaxies, the underlying galaxy is clearly visible in the images and the spectrum.

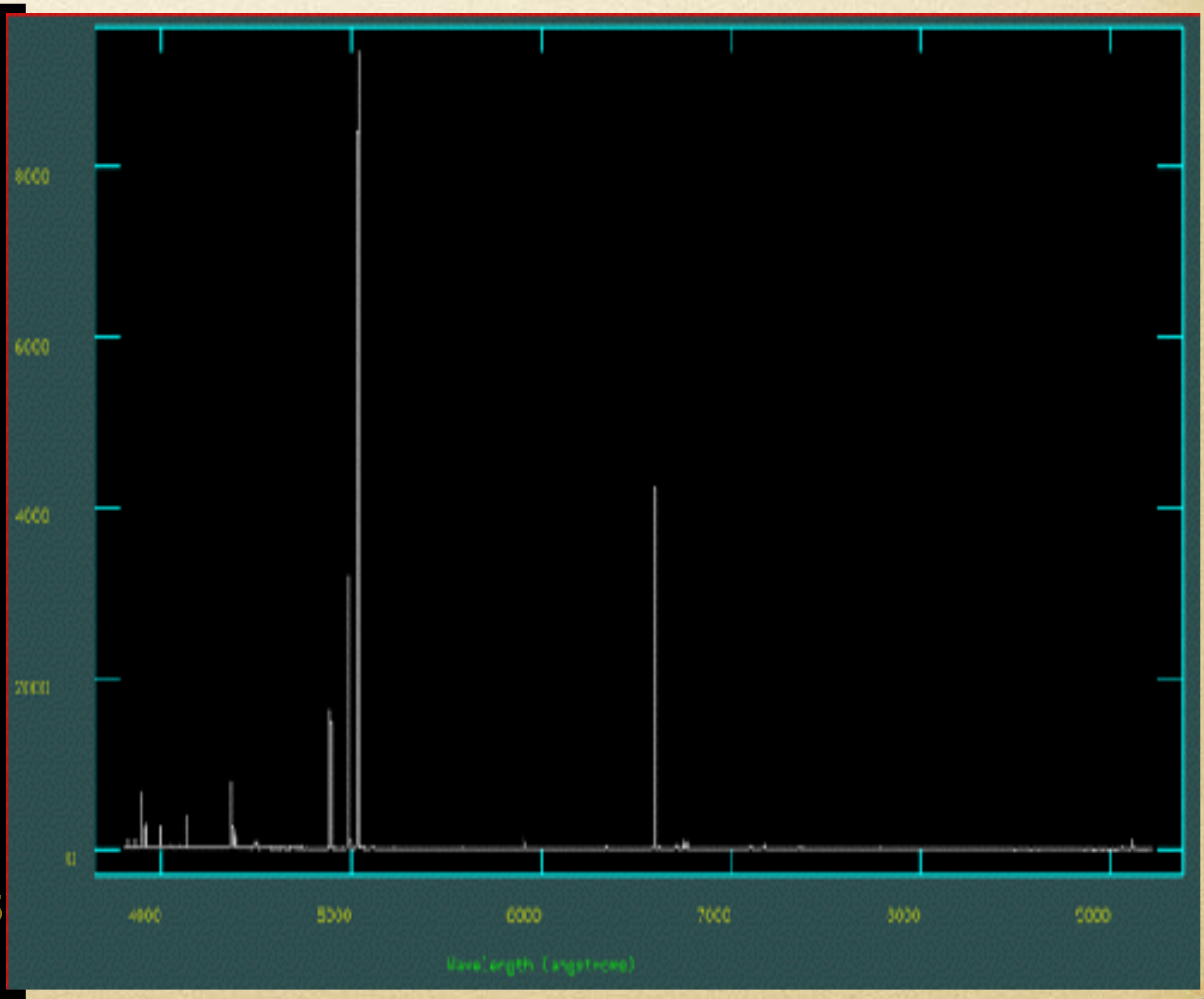
<u>Only those BCD that satisfy the criterion EW(Hα)>200Å are HII galaxies.</u>

<u>HII galaxies are the youngest BCDs.</u>

BCD



HIIGx



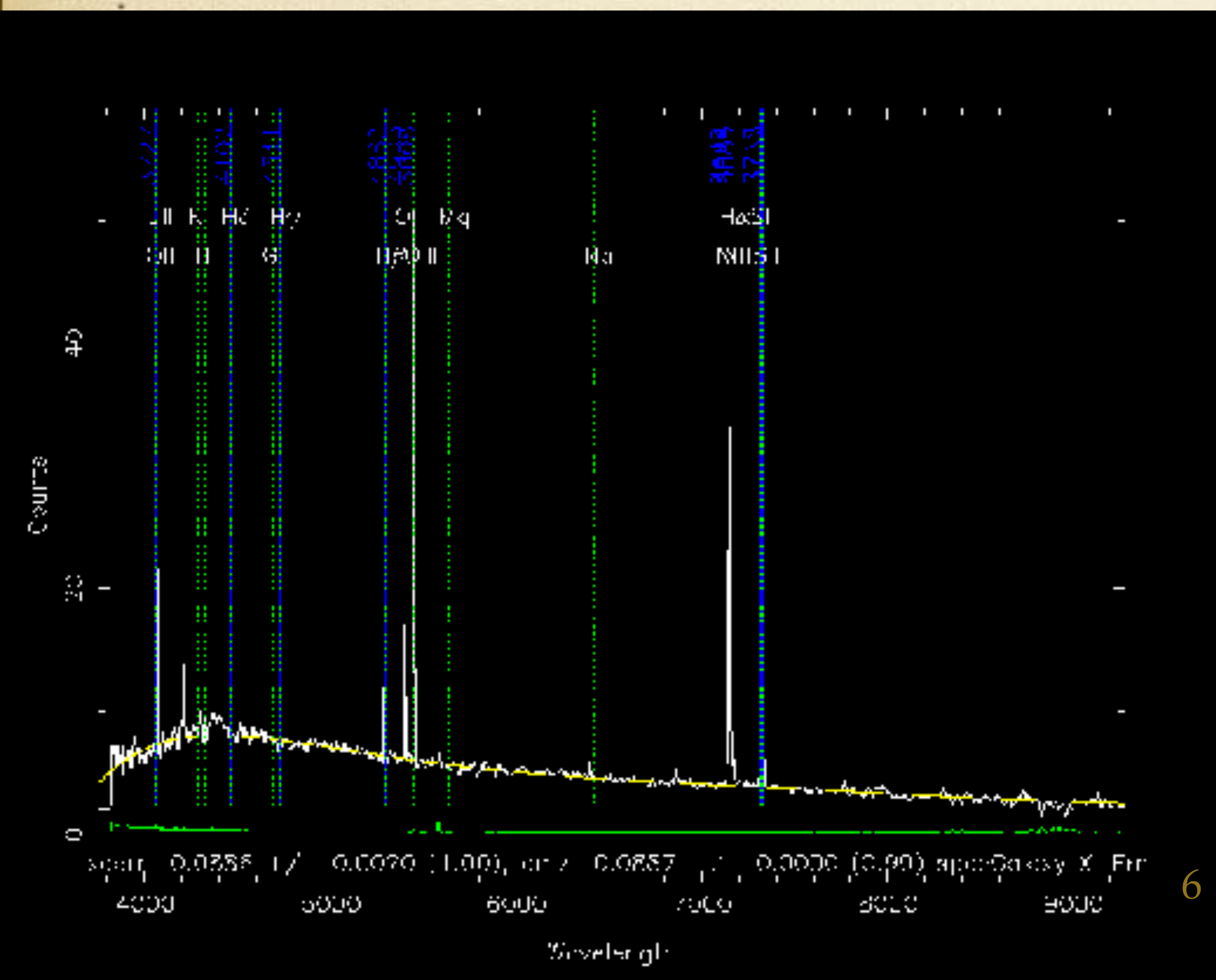
Are BCD HII Galaxies?

Can HII galaxies evolve into BCD?

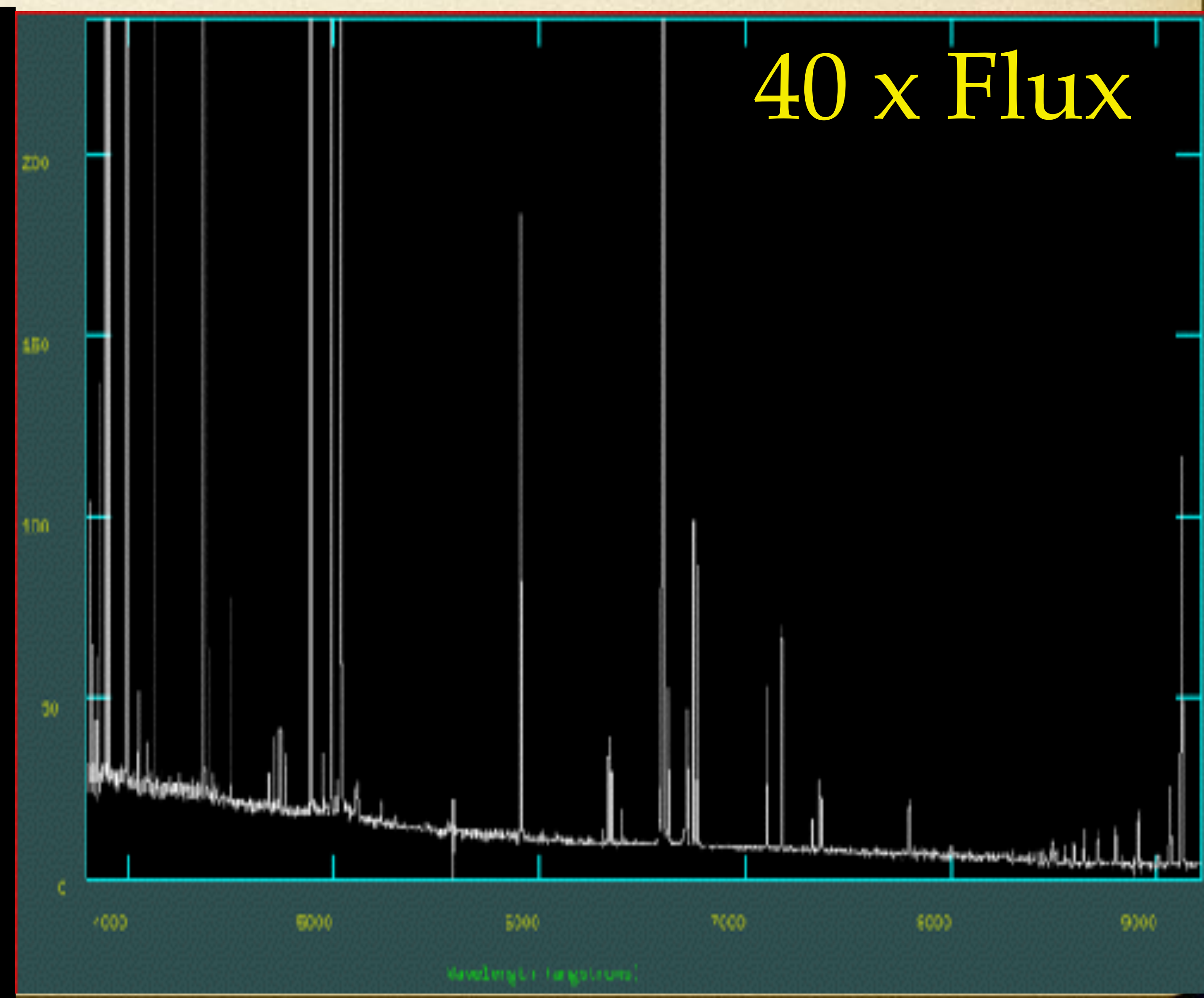
Possibly. As the burst evolves, its luminosity rapidly diminishes and after few million years it becomes less luminous than the parent galaxy.

A problem though is that in general BCDs have higher [O/H] than HIIGx.

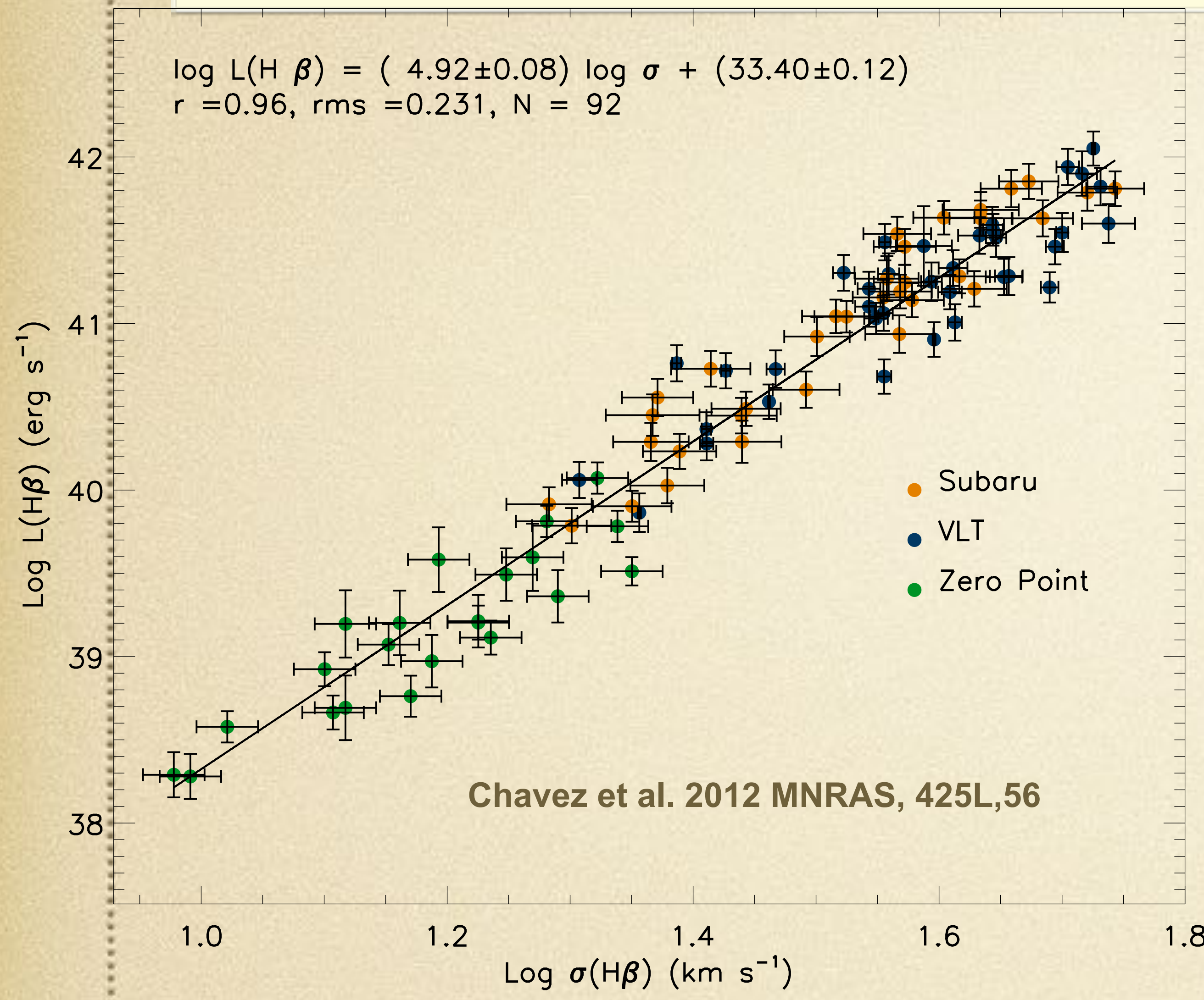
BCD



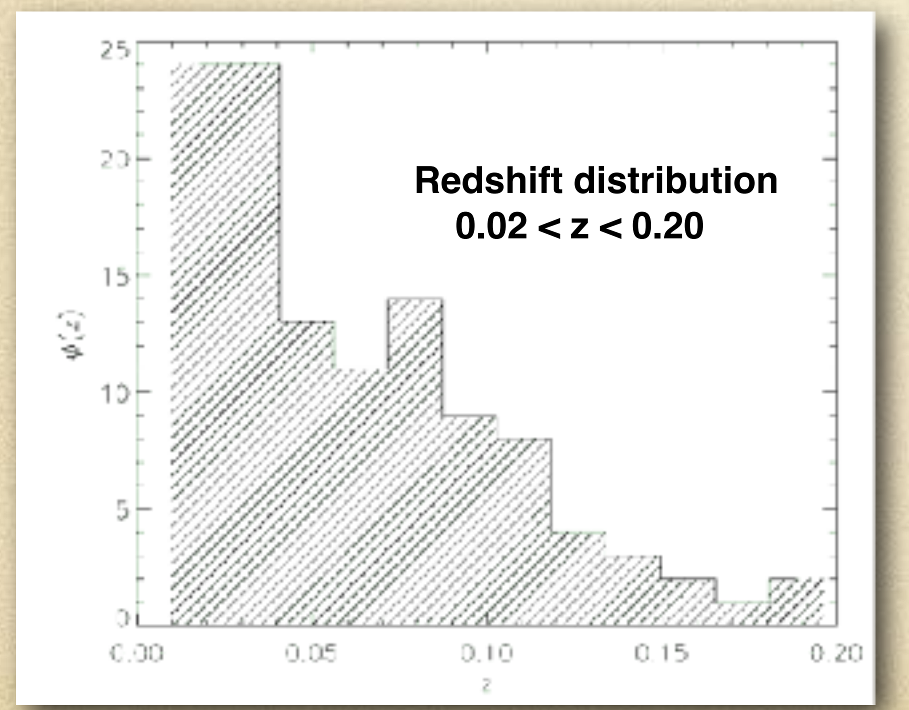
HIIGx

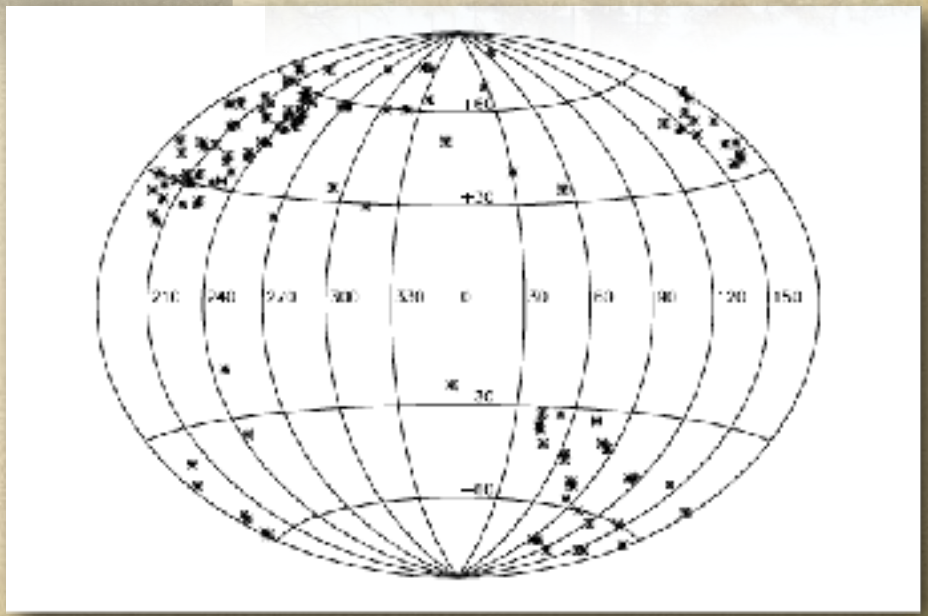


The L-sigma relation for HIIG and GHIIR



Sample of 128 HII galaxies selected from SDSS and SCHIIG

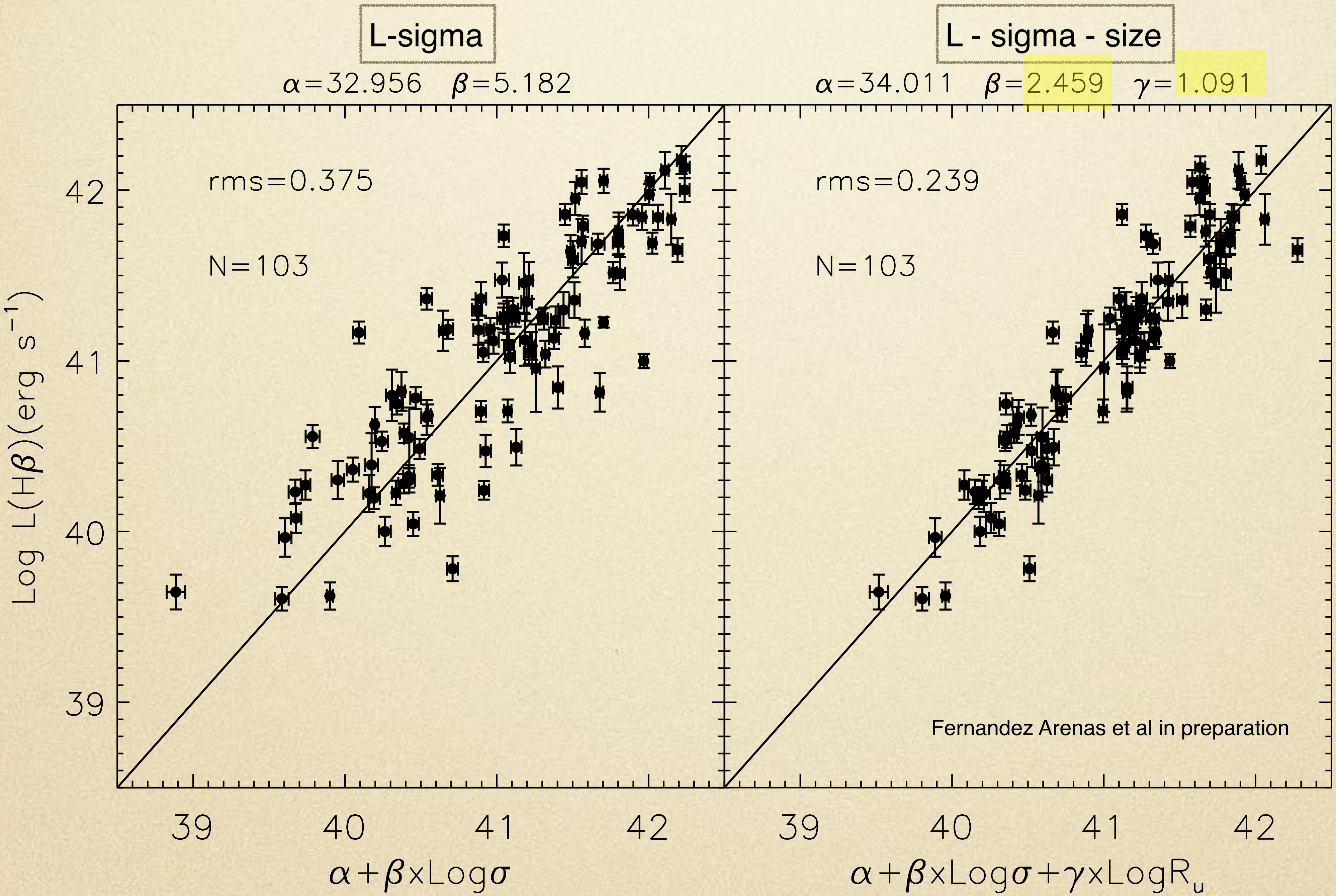




L - sigma Fundamental Plane and the viral theorem

Introducing the size as a second parameter reduces the scatter to the observational errors level.
This indicates that the L-sigma is a 2-D projection of the 3-D fundamental plane, L-sigma-size.

The virial relation predicts exponents 2.0 and 1.0 for the velocity dispersion and size respectively.
The values from the fit to HIIG, 2.46 and 1.1 are not far from the predicted values.



$M_{dynamical}$ vs $M_{stars} + M_{ionized\ gas}$

Comparing the dynamical and photometric masses of HIIG

$M_{ion} = 5.0 \times 10^{-34}\ L(H\beta)\ m_p / \alpha_{eff}(H\beta)\ h\,\nu_{H\beta}\ N_e \quad M_\odot$
$M_{stellar} = 7.1 \times 10^{-34}\ L(H\beta) \quad M_\odot$

$M_{dyn} = k\ G^{-1}\ r_{eff}\ \sigma^2 \quad M_\odot$

This result is very interesting considering the uncertainties involved in these estimates.

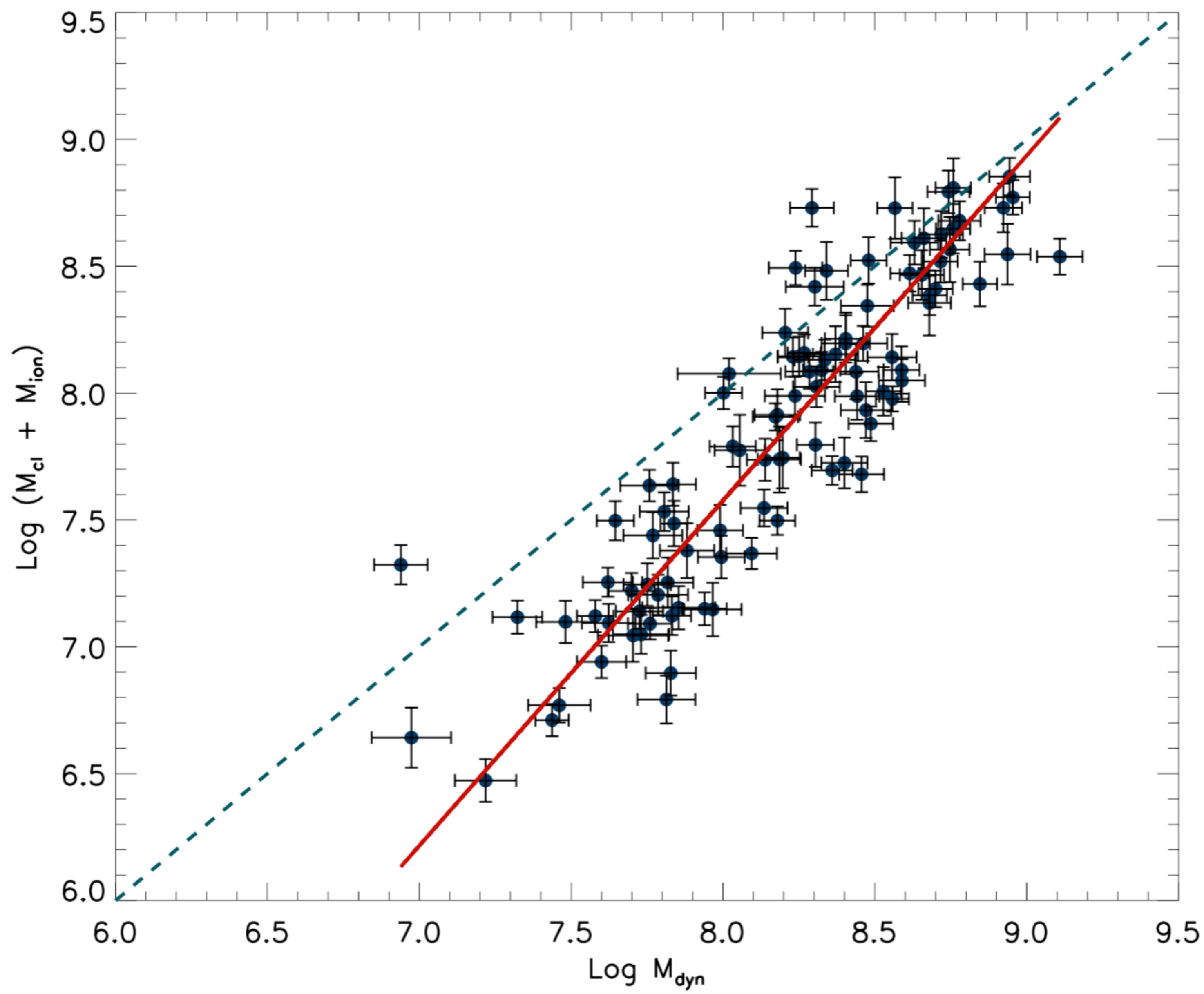


Figure 15. Comparison between $M_{cl} + M_{ion}$ and M_{dyn}. The continuos thick line represents the best fit to the data. The dashed line shows the one-to-one relation.

We postulate that the young massive SSC that ionise the HIIG and GHIIR are gravitationally bound systems and that the velocity dispersion of the ionised gas is a good measure of the depth of the gravitational potential.

Aims

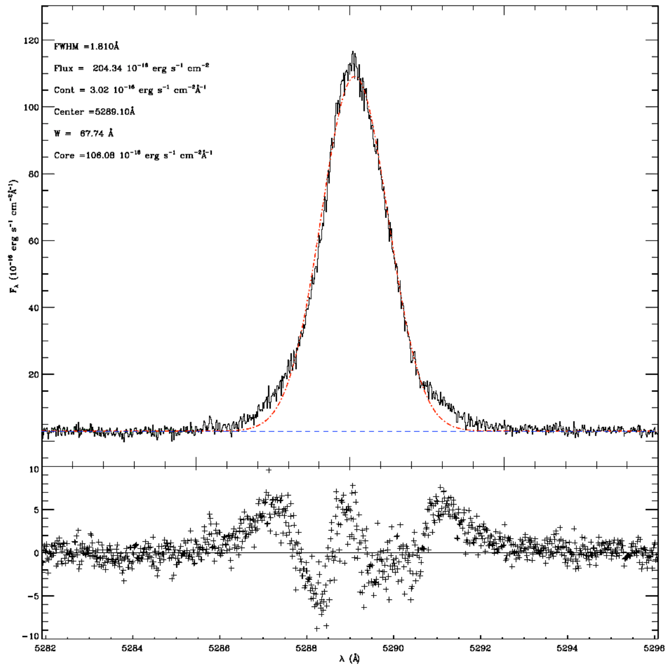
To use the L-sigma distance indicator to measure H_0, Ωm , w0 and w1.

I will first discuss the determination of the Hubble constant Ho, then the determination of Ωm and the equation of state of the dark energy w.

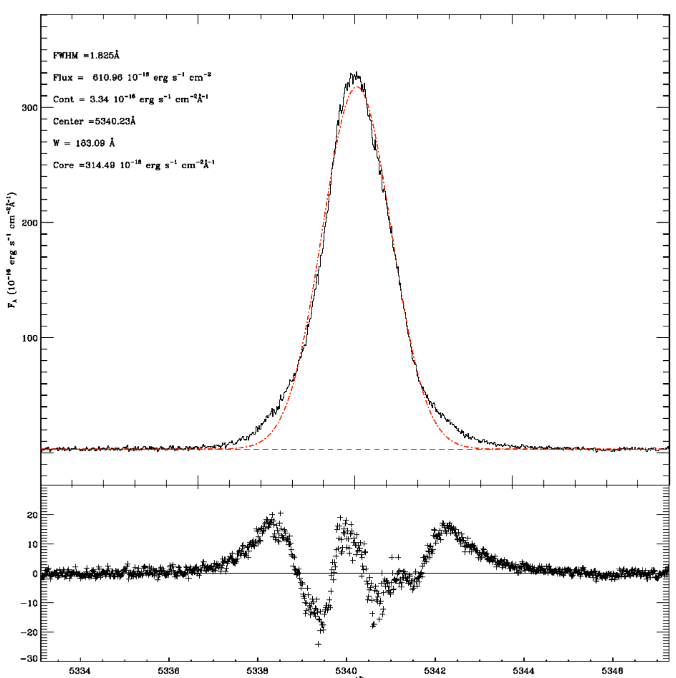
Finally I will touch on the implications for a universal IMF.

Velocity dispersions: UVES Data

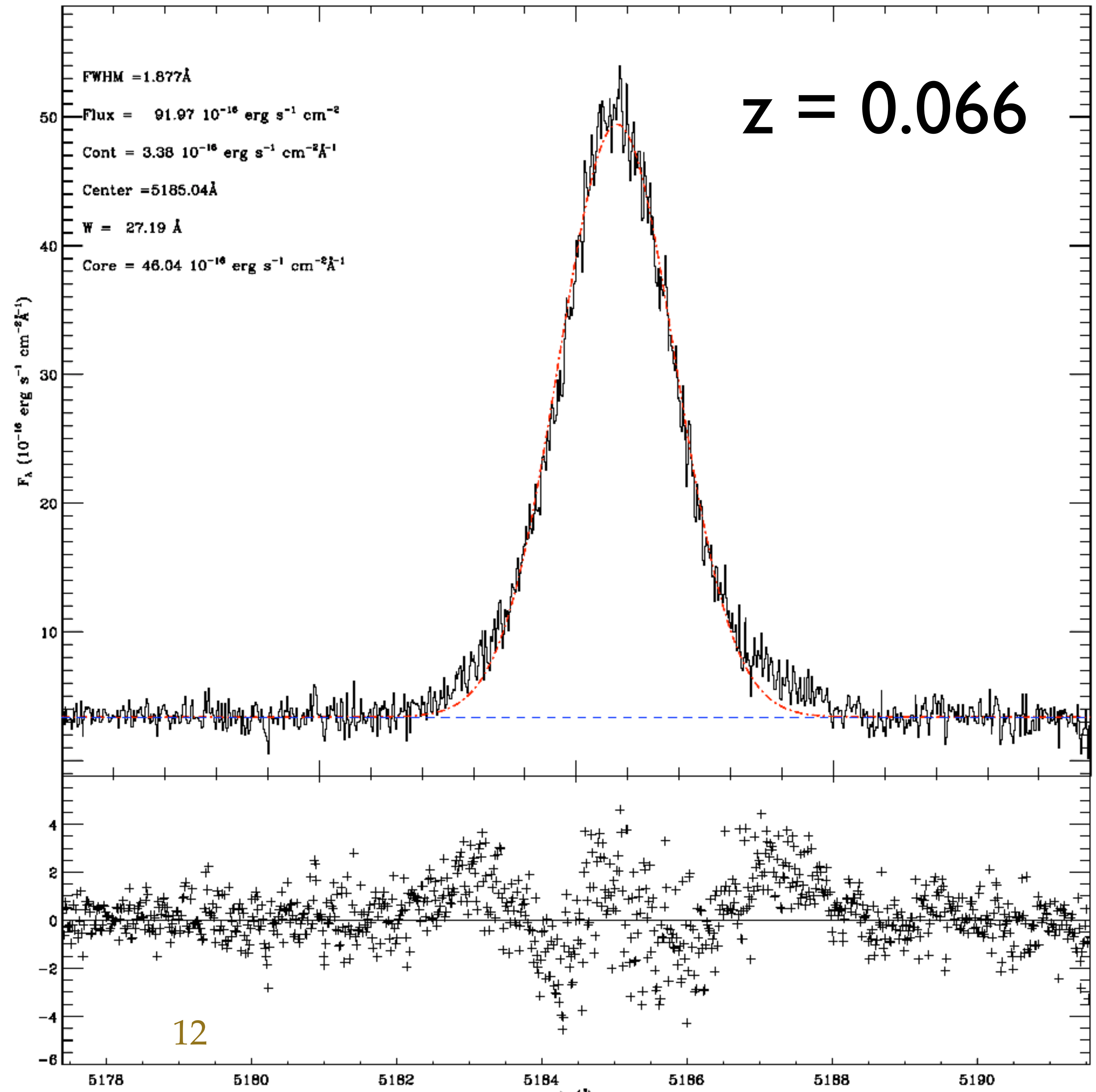
[O III] λ 4959



[O III] λ 5007



J222510-001152 Hβ



Typical GHIIR data

Fernandez Arenas et al 2017

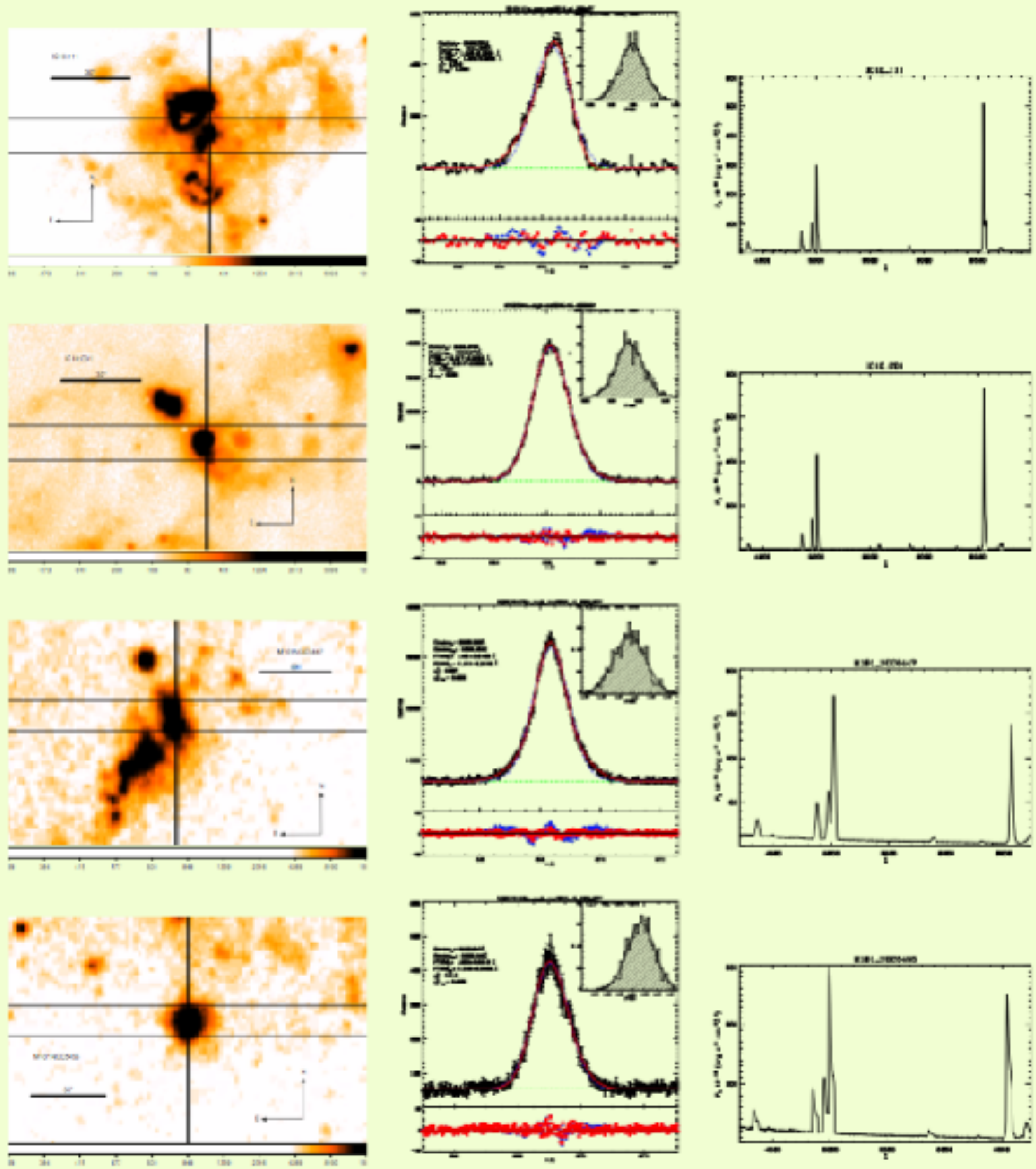
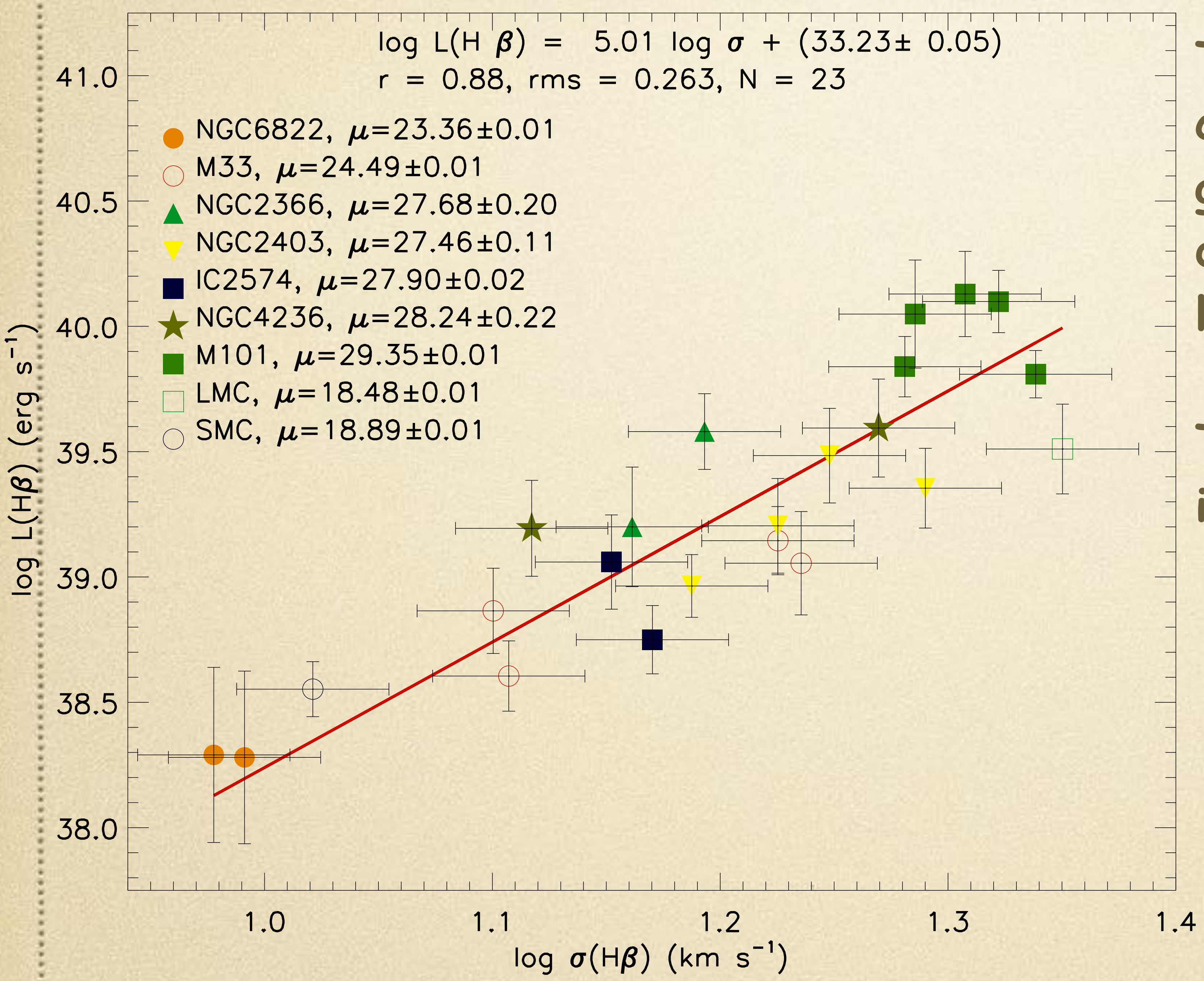


Figure B1. Hα image obtained from NASA/IPAC Extragalactic Database (NED), high-resolution profile for the GHIIRs and low-resolution spectrum.

Measuring H_0 - The L-σ relation of the anchor sample



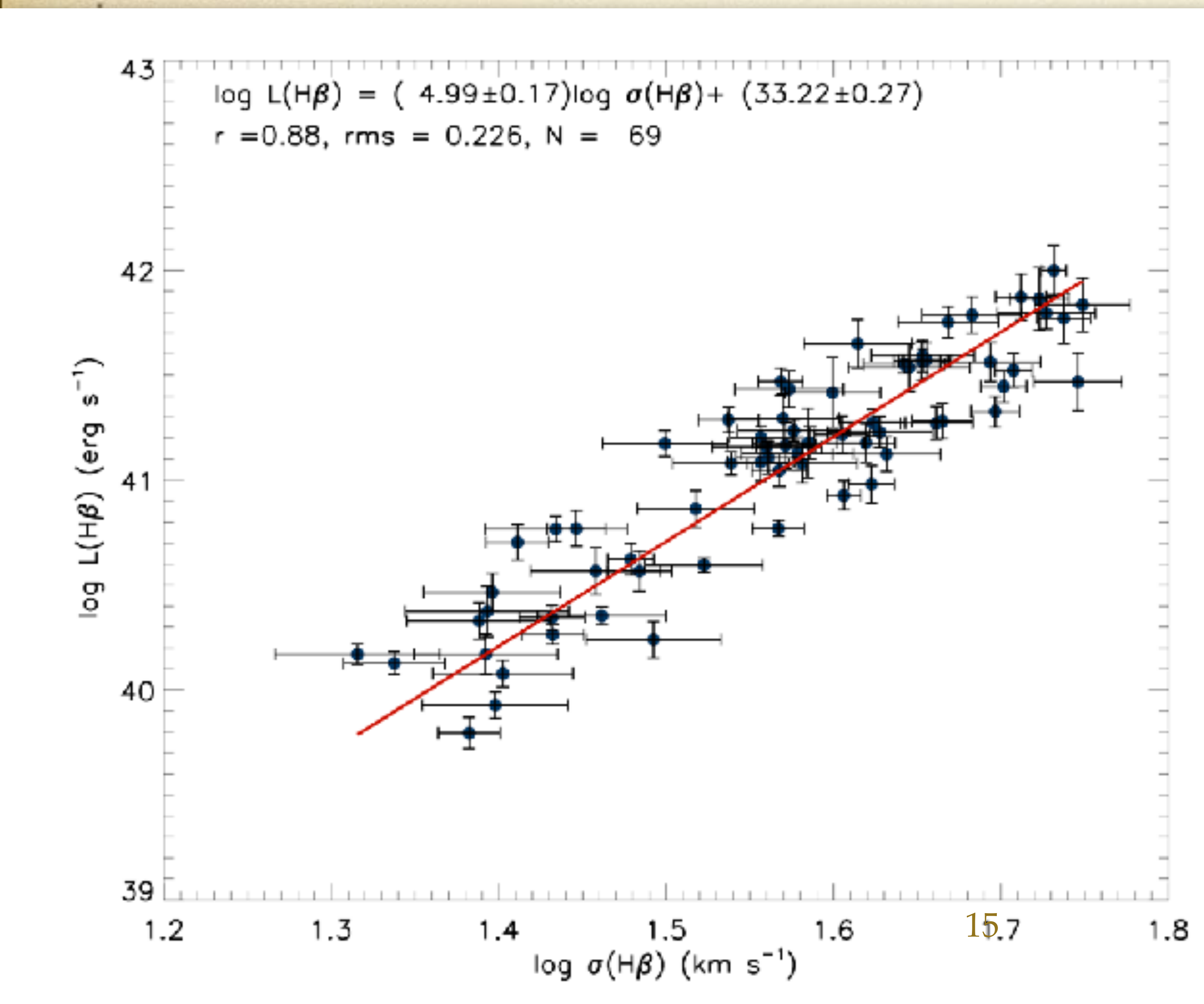
The anchor sample is composed by GHIIR in galaxies with distances determined using Cepheid light curves.

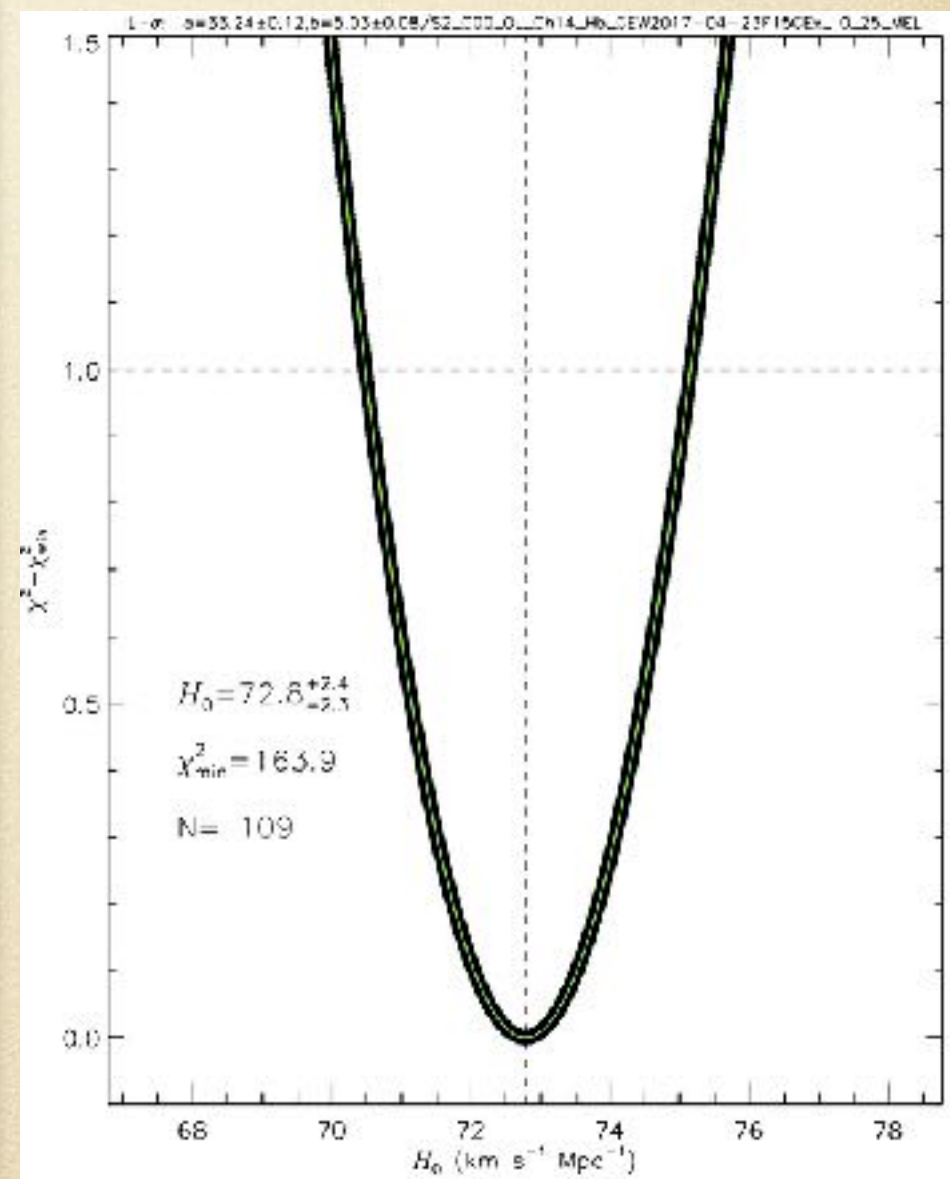
The luminosity of GHIIR is independent of H_0 .

Measuring H_0 -The L-σ relation of the H II Galaxies

The luminosity of HIIG depends of H_0 .

χ^2 solution





Measuring H_0: Results

We obtained:

Chavez etal 2012 H_0=74.3 ± 4.2 (random+systematic)

Fernandez-Arenas etal 2017 H_0=71.0 ± 3.5 (random+systematic)

In excellent agreement with SNIa determinations:

Freedman etal 2001: H_0 = 72 ± 8 (random+systematic)

Sandage etal 2006: H_0 = 62.3 ± 5.0 (random+systematic)

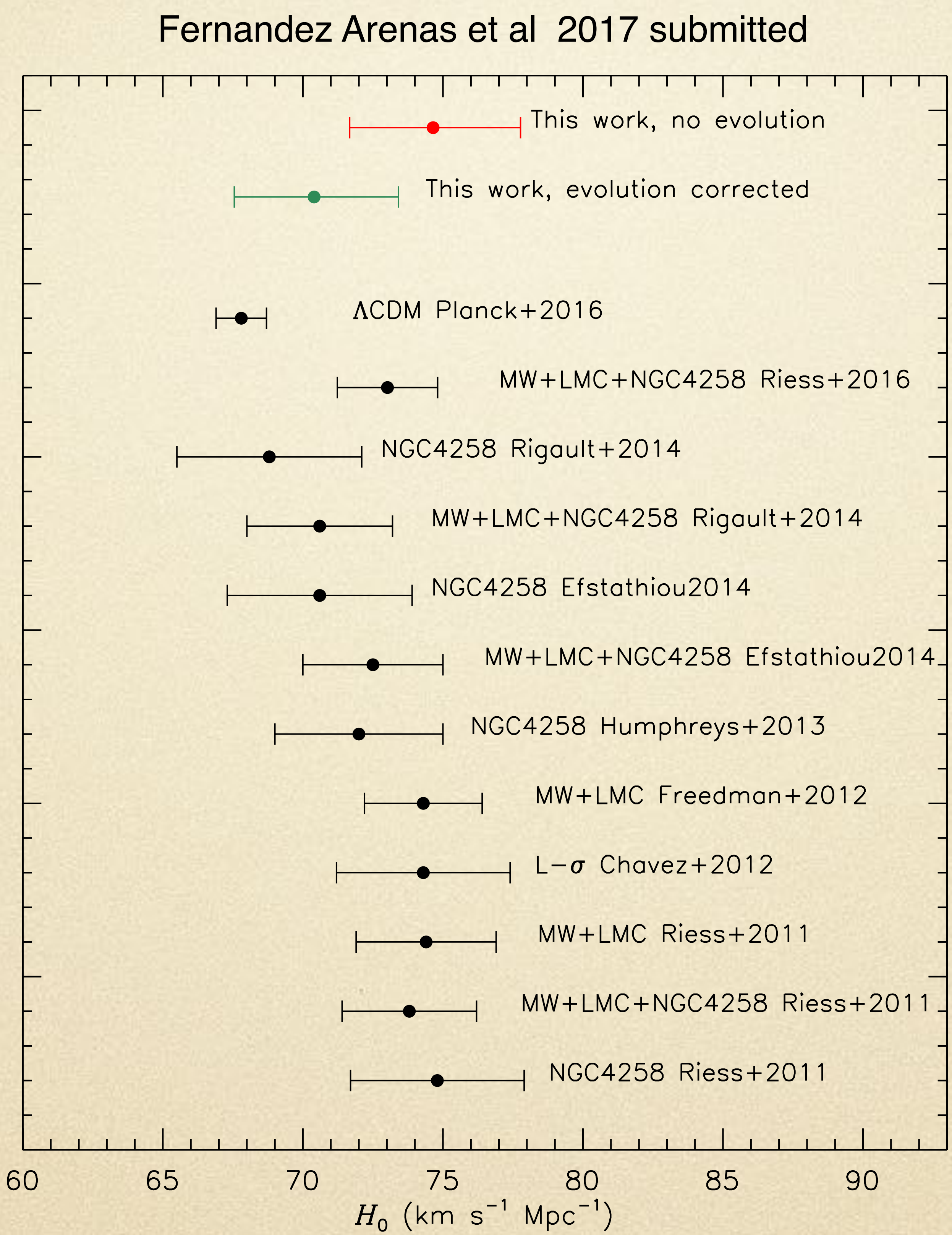
Riess etal 2009: H_0 = 74.2 ± 3.6 (random+systematic)

Riess etal 2012: H_0 = 73.8 ± 2.4 (random+systematic)

Freedman etal 2012: H_0 = 74.3 ± 2.6 (random+systematic)

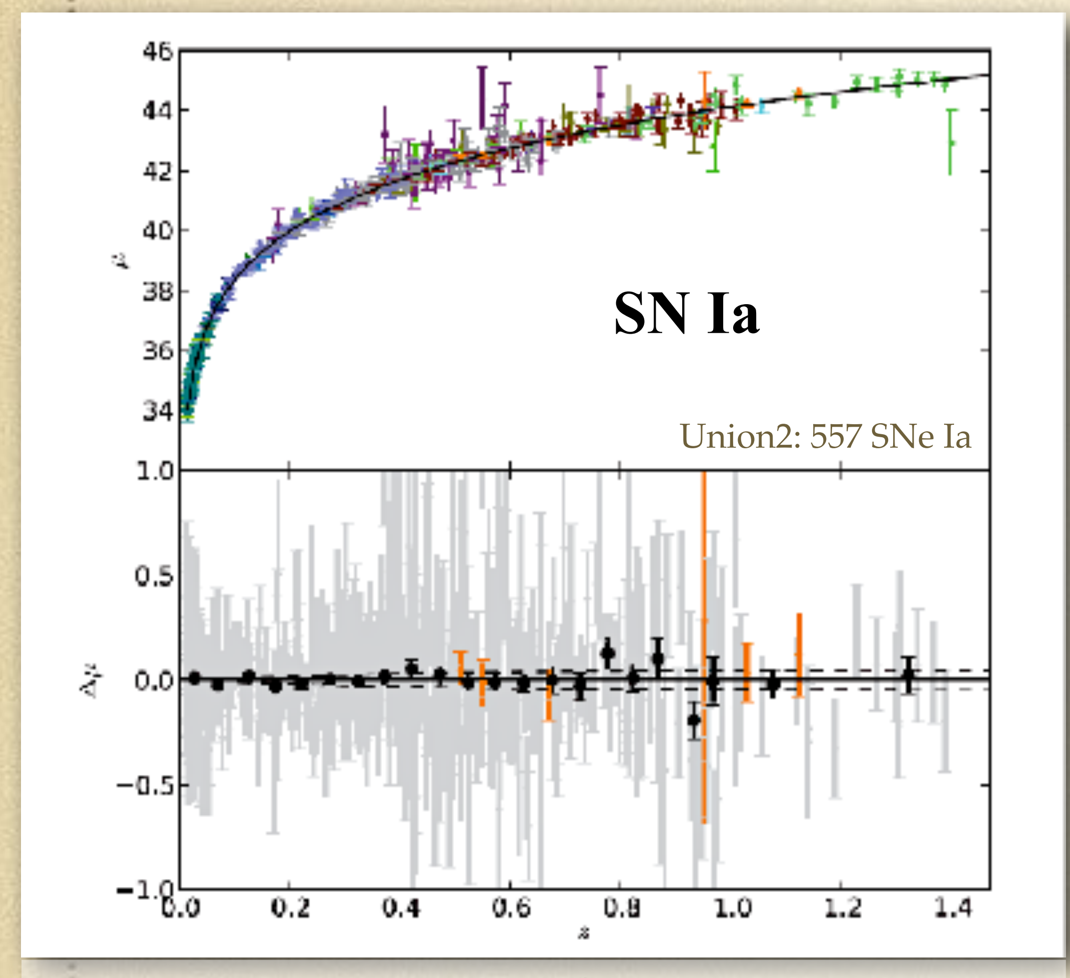
Riess etal 2016: H_0 = 73.2 ± 1.7 (random+systematic)

H0 results

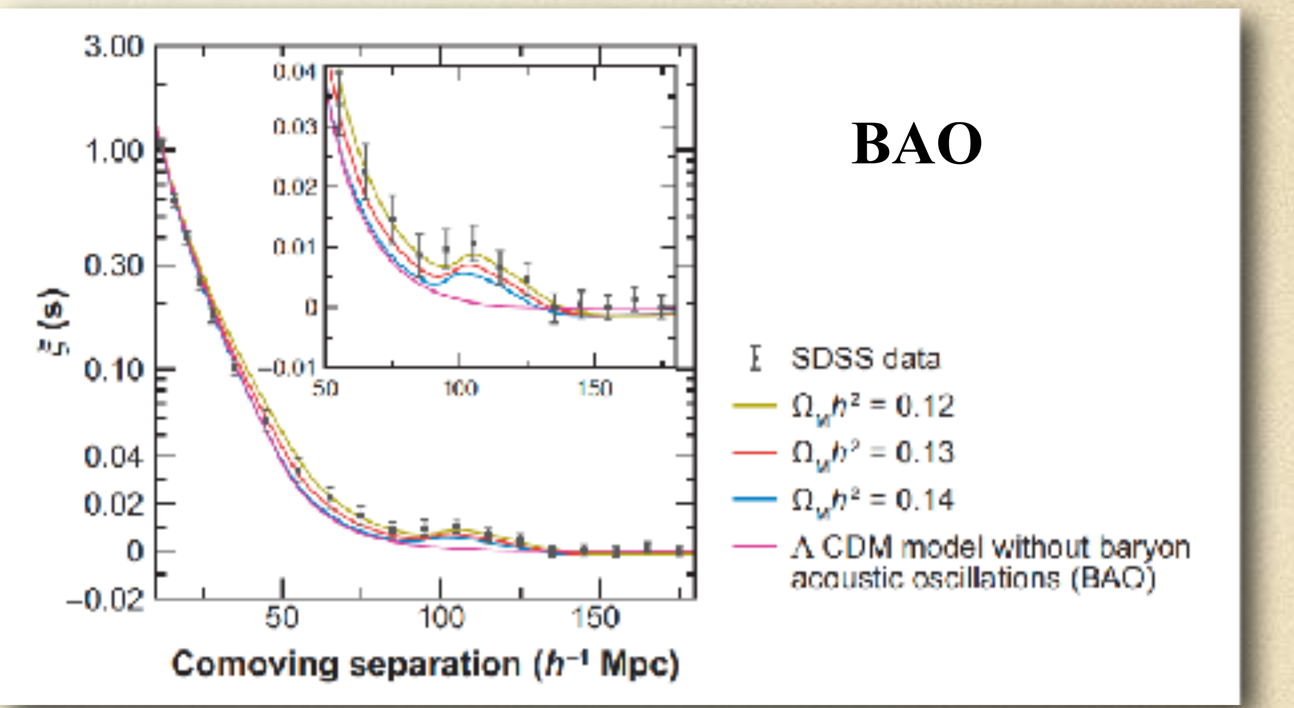


Fernandez Arenas et al 2017 submitted
This work, no evolution
This work, evolution corrected
ΛCDM Planck+2016
MW+LMC+NGC4258 Riess+2016
NGC4258 Rigault+2014
MW+LMC+NGC4258 Rigault+2014
NGC4258 Efstathiou2014
MW+LMC+NGC4258 Efstathiou2014
NGC4258 Humphreys+2013
MW+LMC Freedman+2012
L−σ Chavez+2012
MW+LMC Riess+2011
MW+LMC+NGC4258 Riess+2011
NGC4258 Riess+2011
60
65
70
75
80
85
90
H_0 (km s^{-1} Mpc^{-1})

Dark Energy - The Observational Landscape

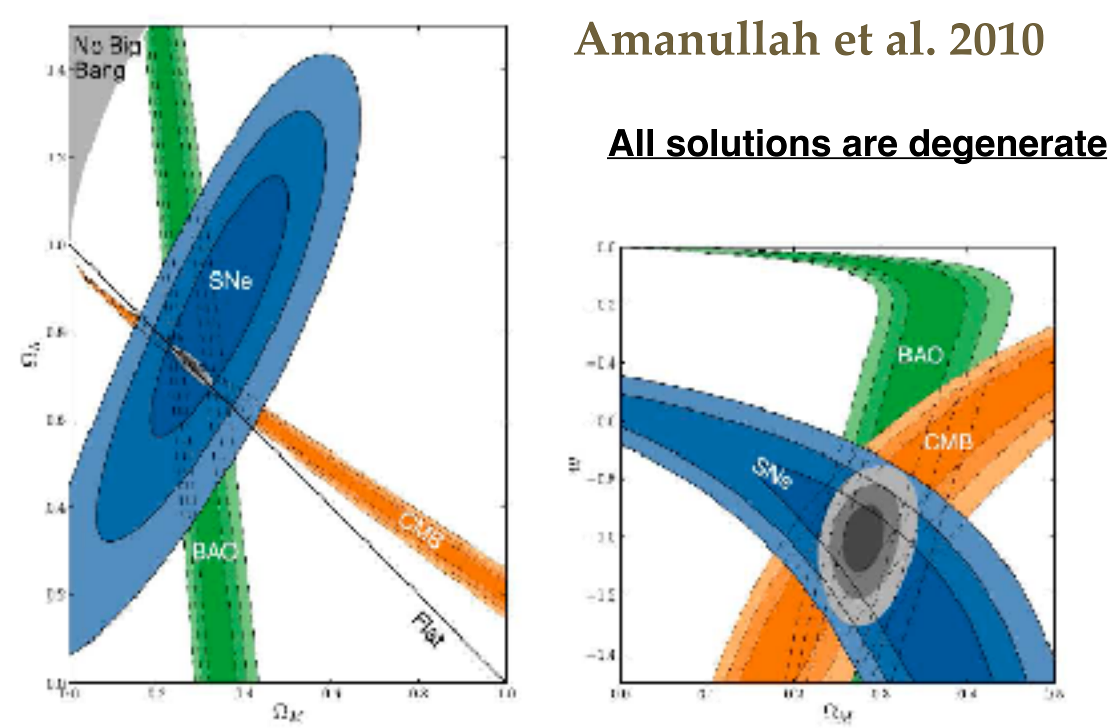


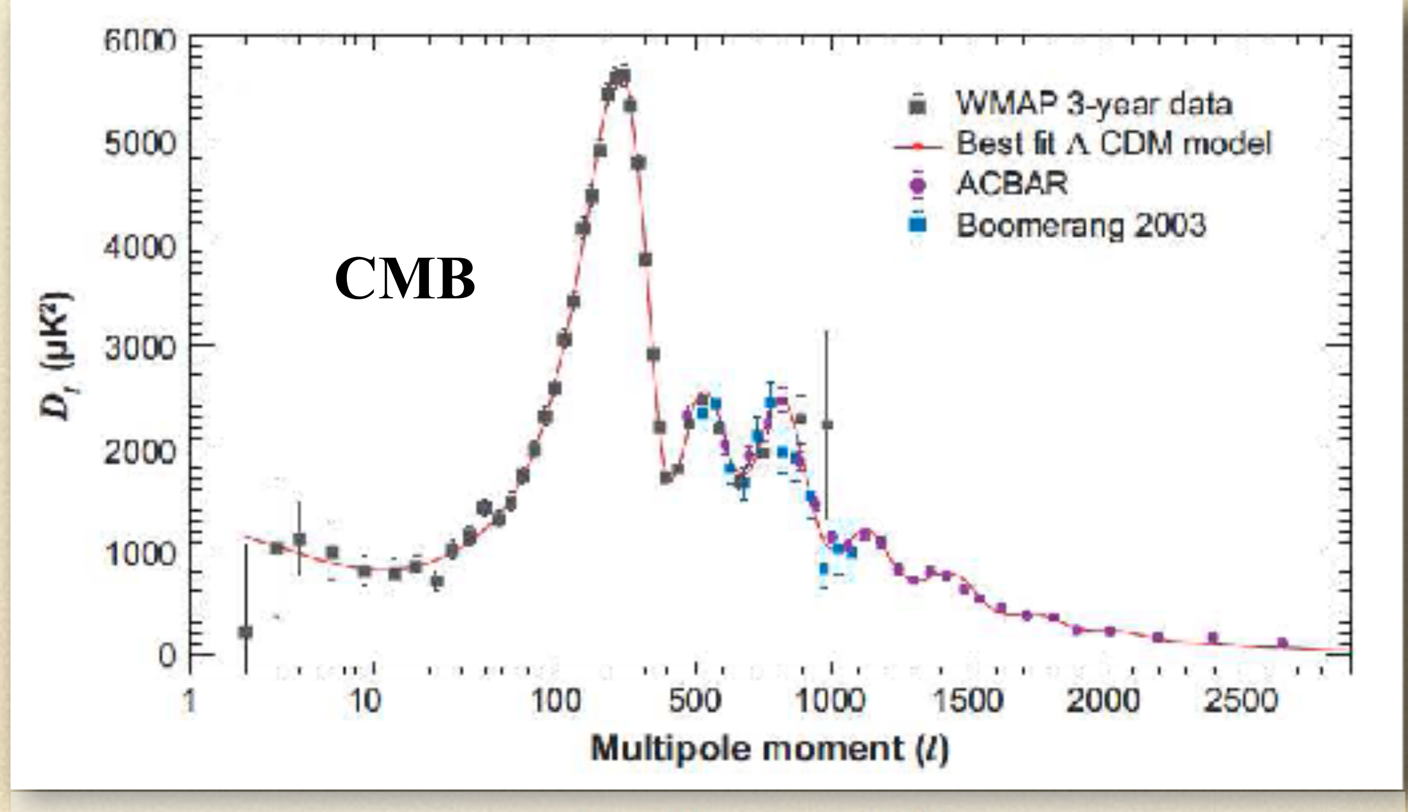
Union2: 557 SNe Ia



Amanullah et al. 2010

All solutions are degenerate





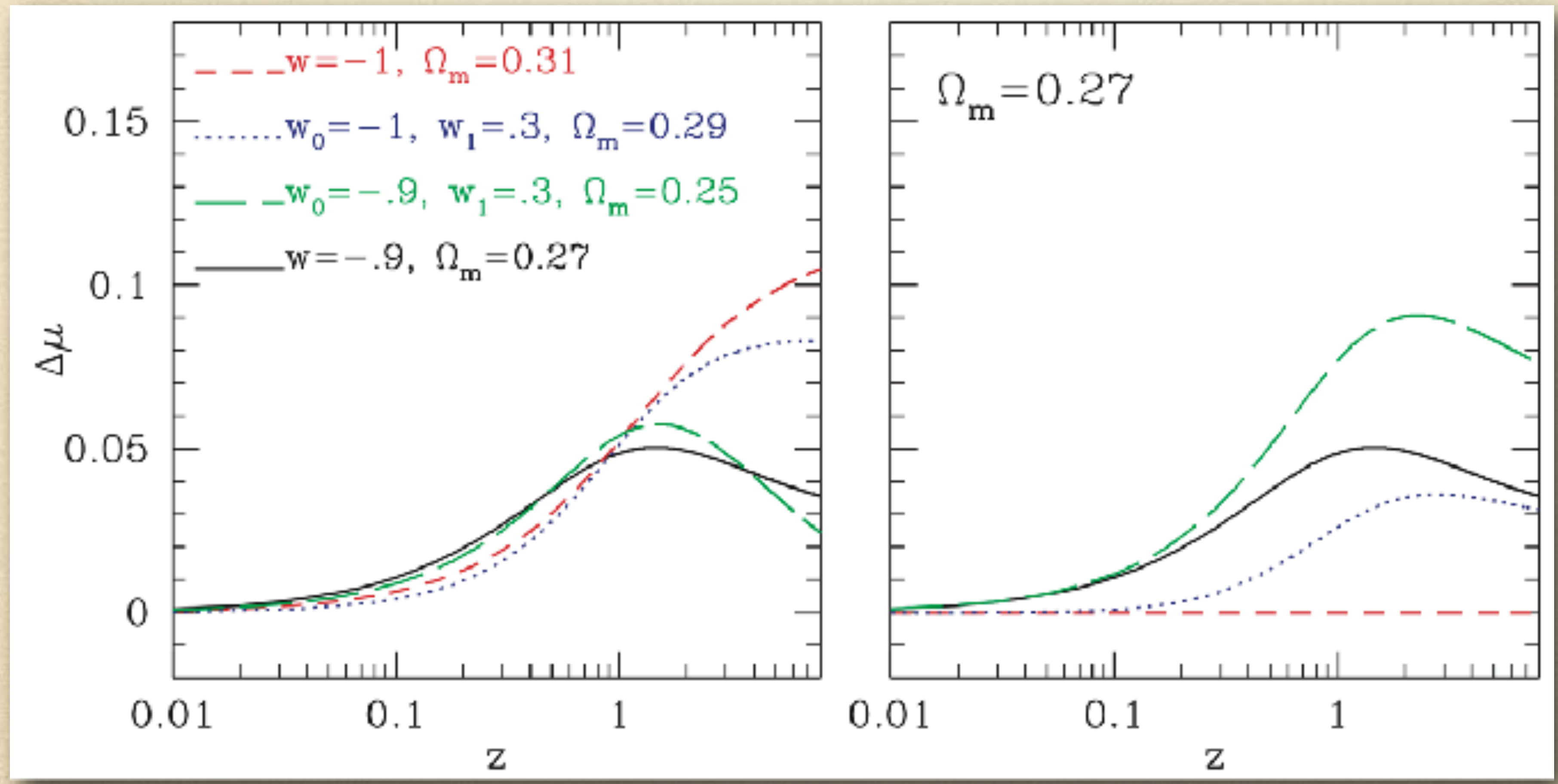
From Frieman et al. 2008

Manifestations of different Dark Energy models

The plot shows the relative distance modulus, $\Delta\mu=\Delta(m-M)$, between different models.

Even with fixed Ω_m there are important $\Delta\mu$ differences with respect to a reference model ($w=-1$, $\Omega_m=0.27$) due to w variation and/or w evolution.

Maximum $\Delta\mu$ variation occurs at z>2, i.e. out of reach of current SN Ia surveys.

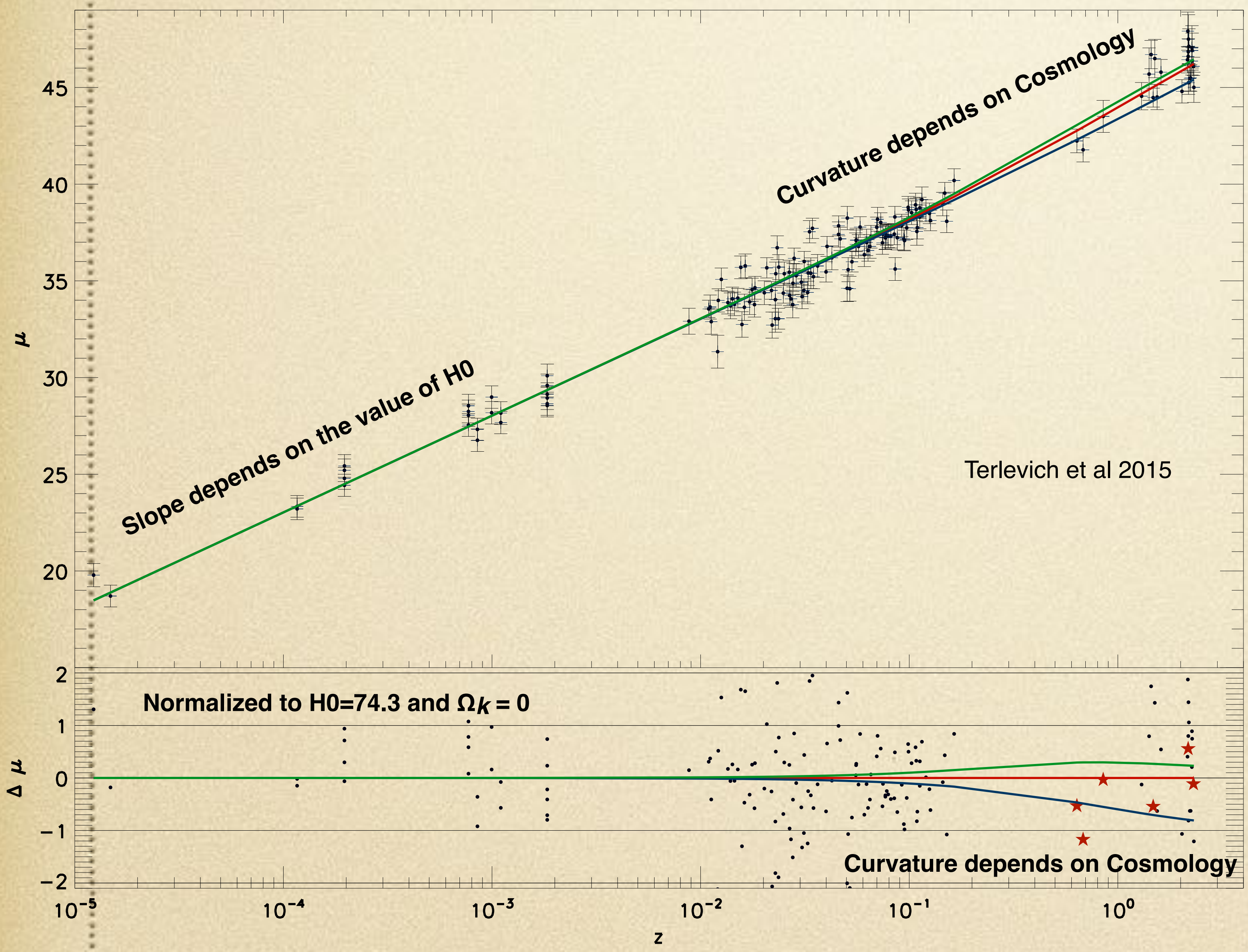


Plionis etal 2011, MNRAS.416.2981

Left Panel: The expected distance modulus difference between the DE models shown and the reference Λ-model ($w=-1$) with Ωm = 0.27. Right Panel: The expected distance modulus differences once the Ωm-w(z) degeneracy is broken (imposing the same Ωm value as in the comparison model).

The GHIIR and HIIG Hubble diagram

This Hubble diagram includes 25 high z, and 109 nearby HIIG plus 23 GHIIR.
All lines are for H_0 = 74.3 and Ω_k = 0.



Hubble diagram for three different cosmologies.

The red line indicates the concordance CDM cosmology: Ω_m = 0.3 ; w_0 = −1.0.

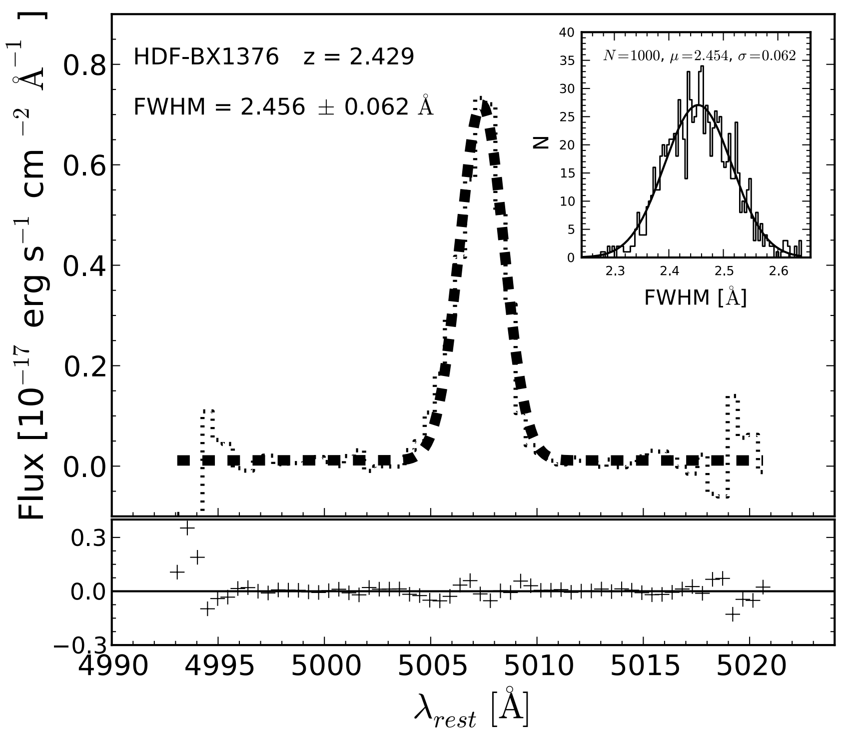
The green line shows a cosmology with Ω_m = 0.3 ; w_0 = −2.0.

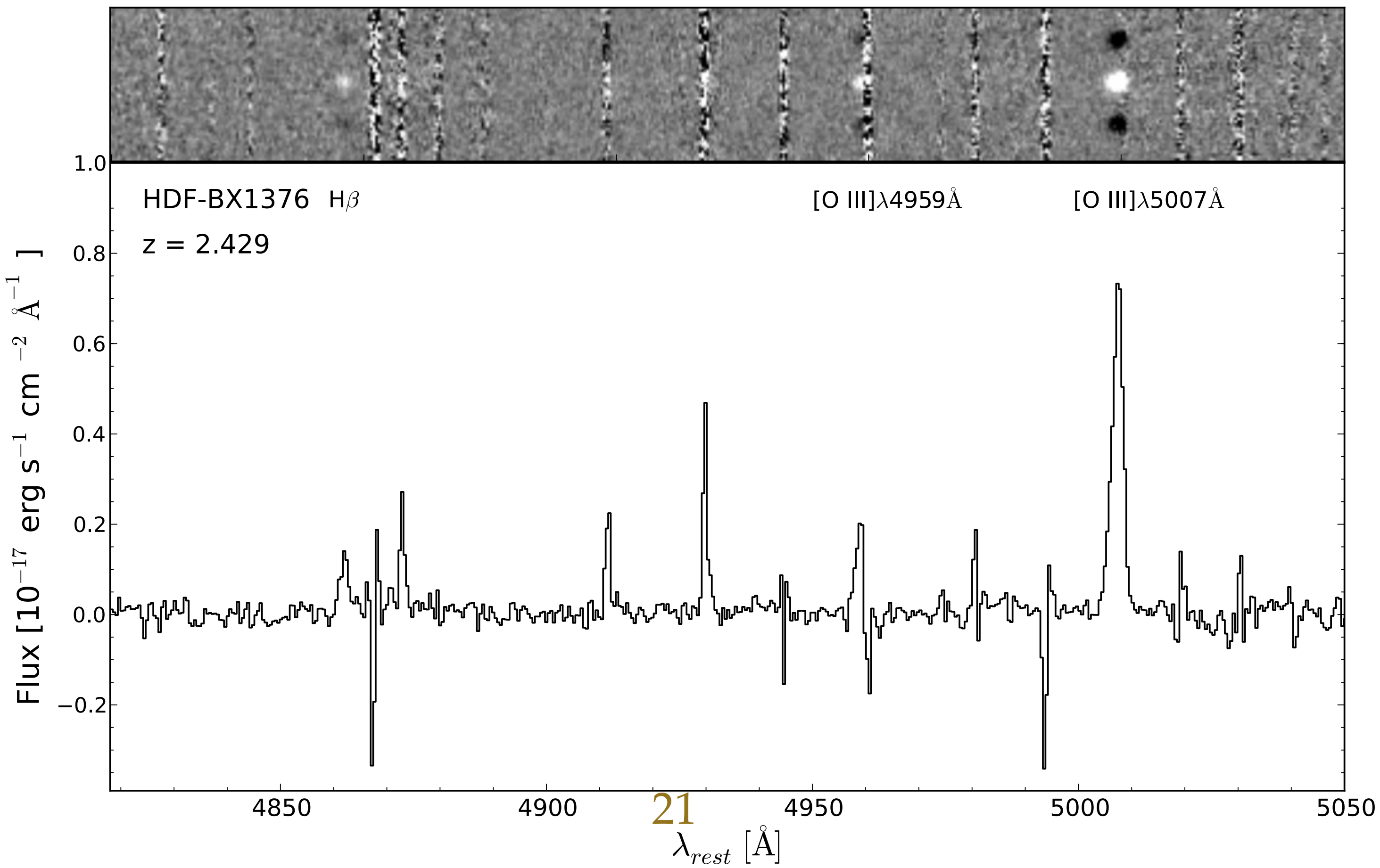
The blue line shows a cosmology with Ω_m = 1.0 ; w_0 = −1.0.

Residuals are plotted in the bottom panel.

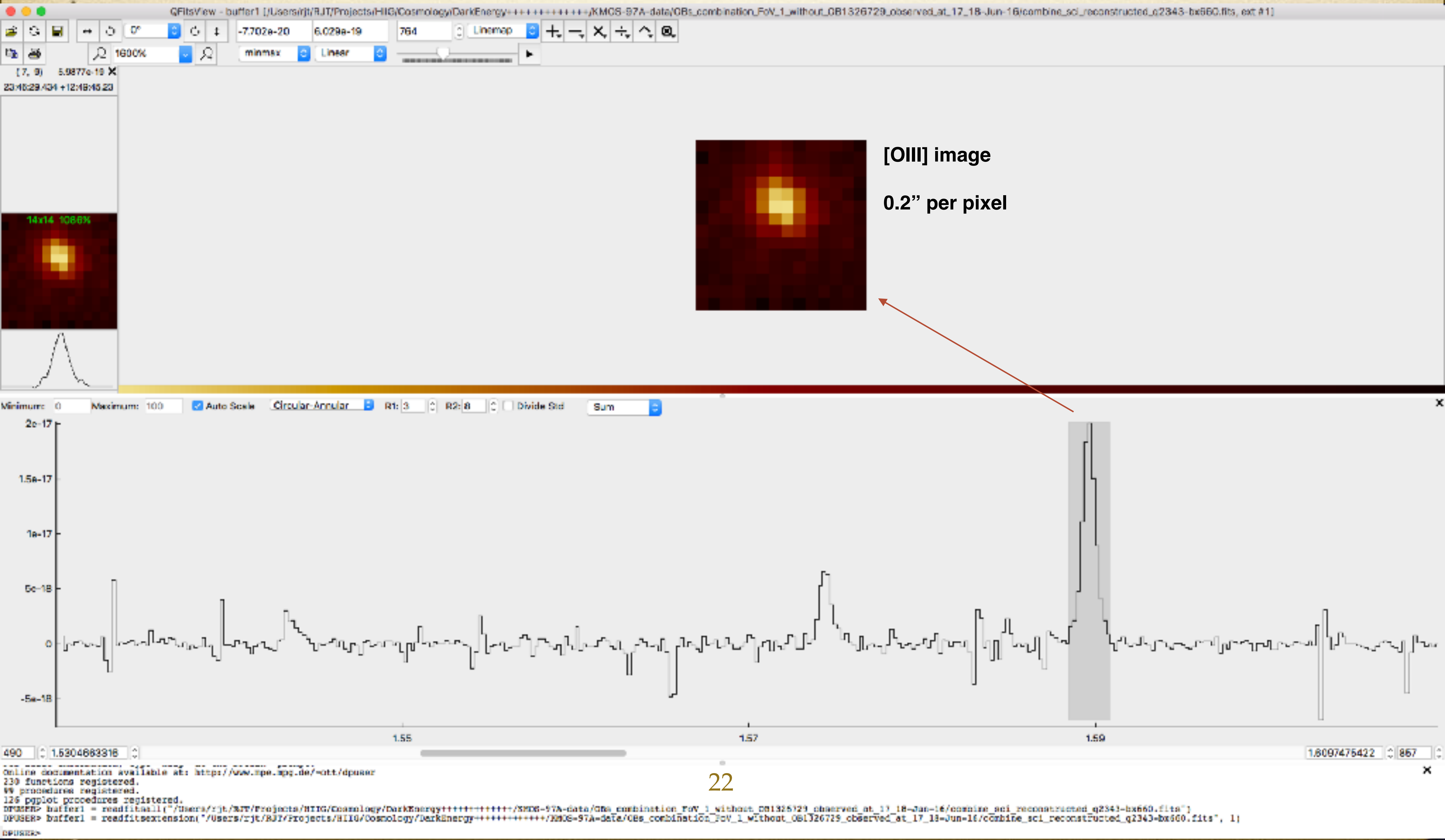
Note the huge dynamical range in distance modulus of almost 30 mag covered with the L–sigma distance indicator.

HIIG at z=2.43 observed with MOSFIRE at KECK

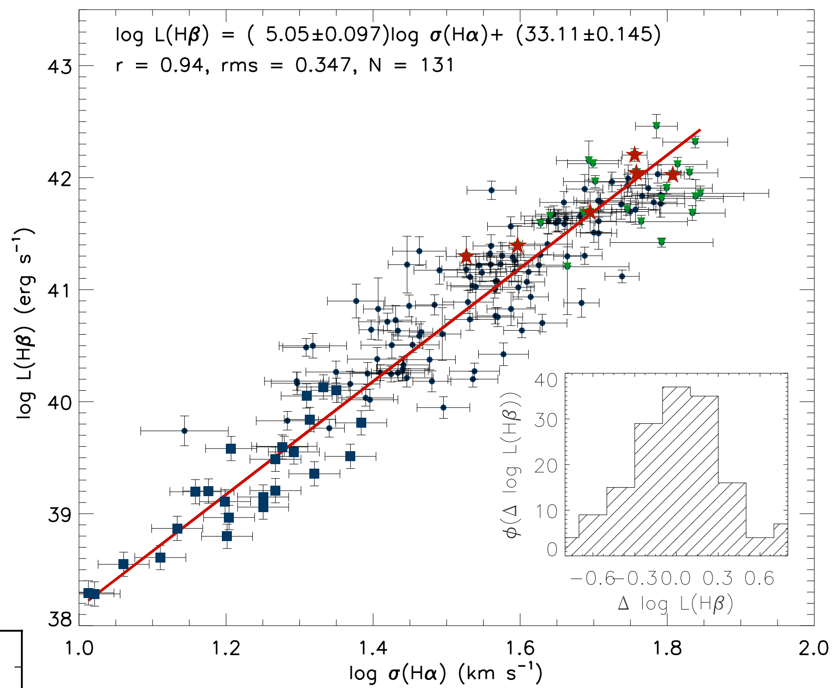


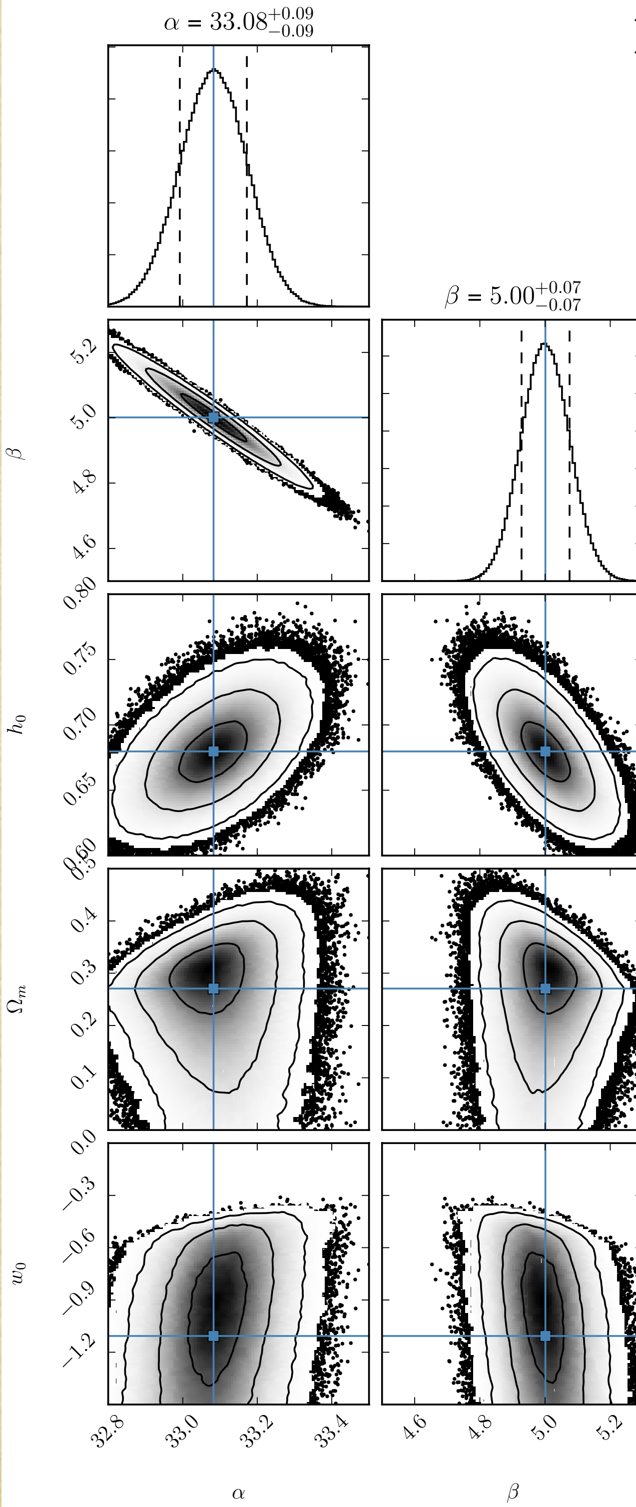
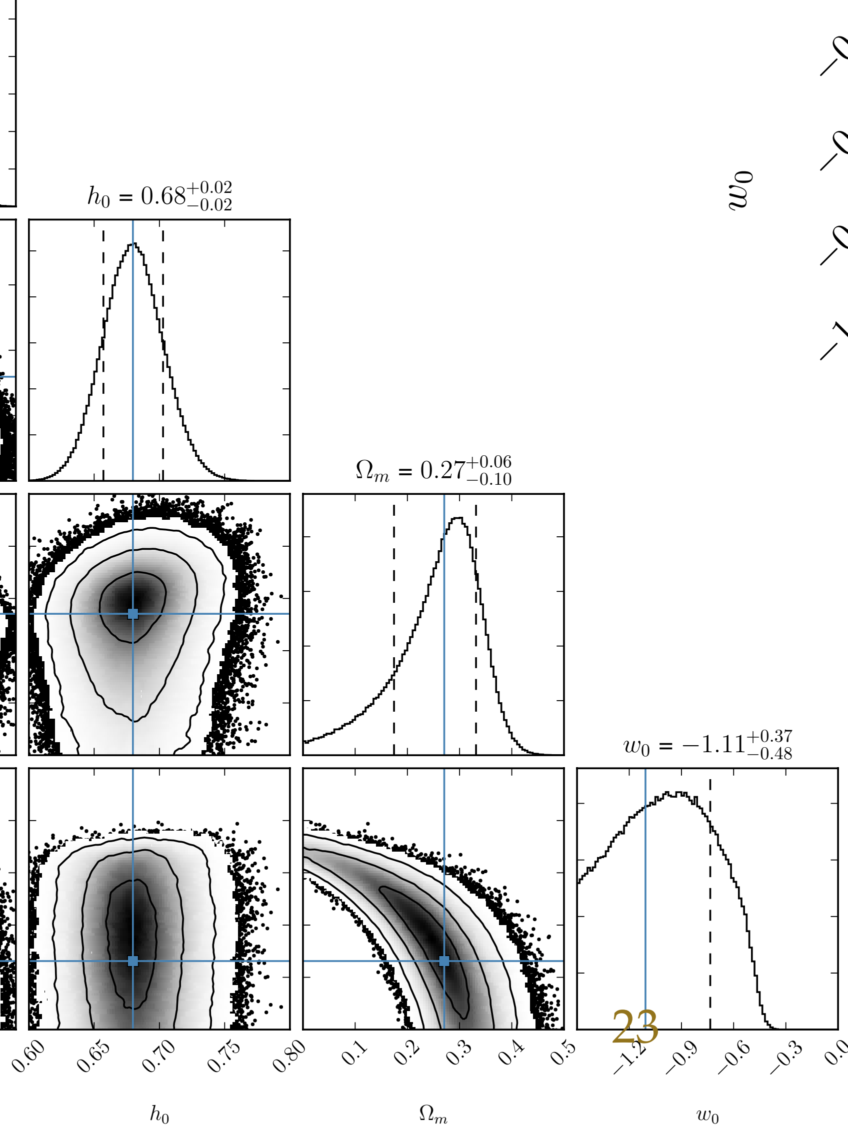


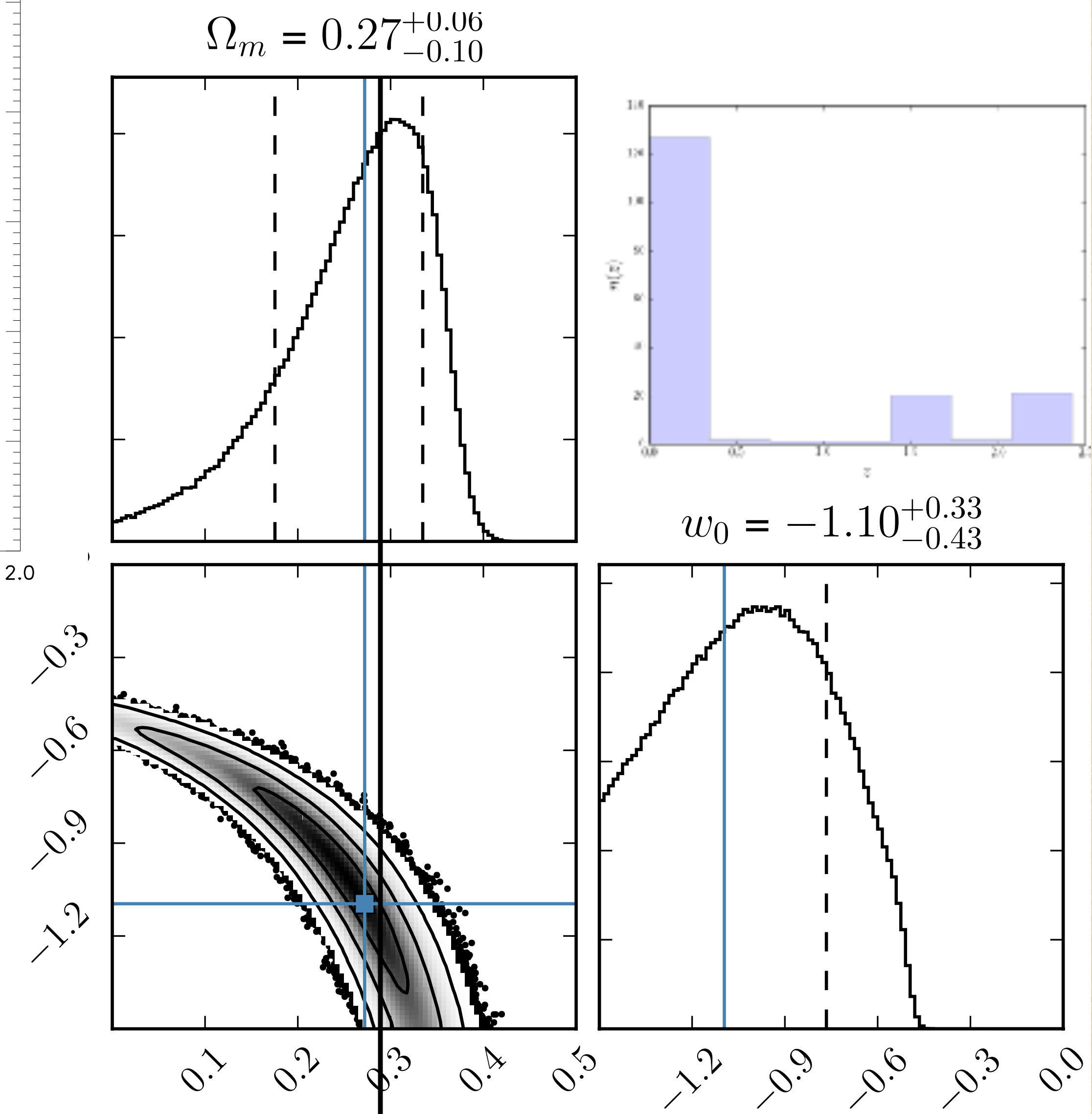
HIIG at z=2.17 observed with KMOS at VLT

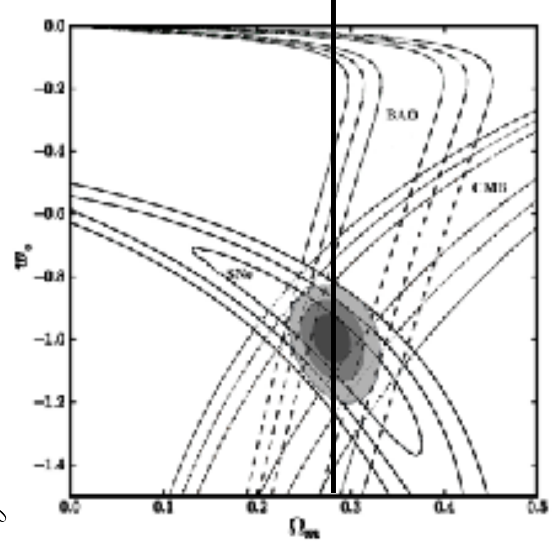


Preliminary results including high z HIIG







From Suzuki et al 2012

Preliminary results including our MOSFIRE high z HIIG data

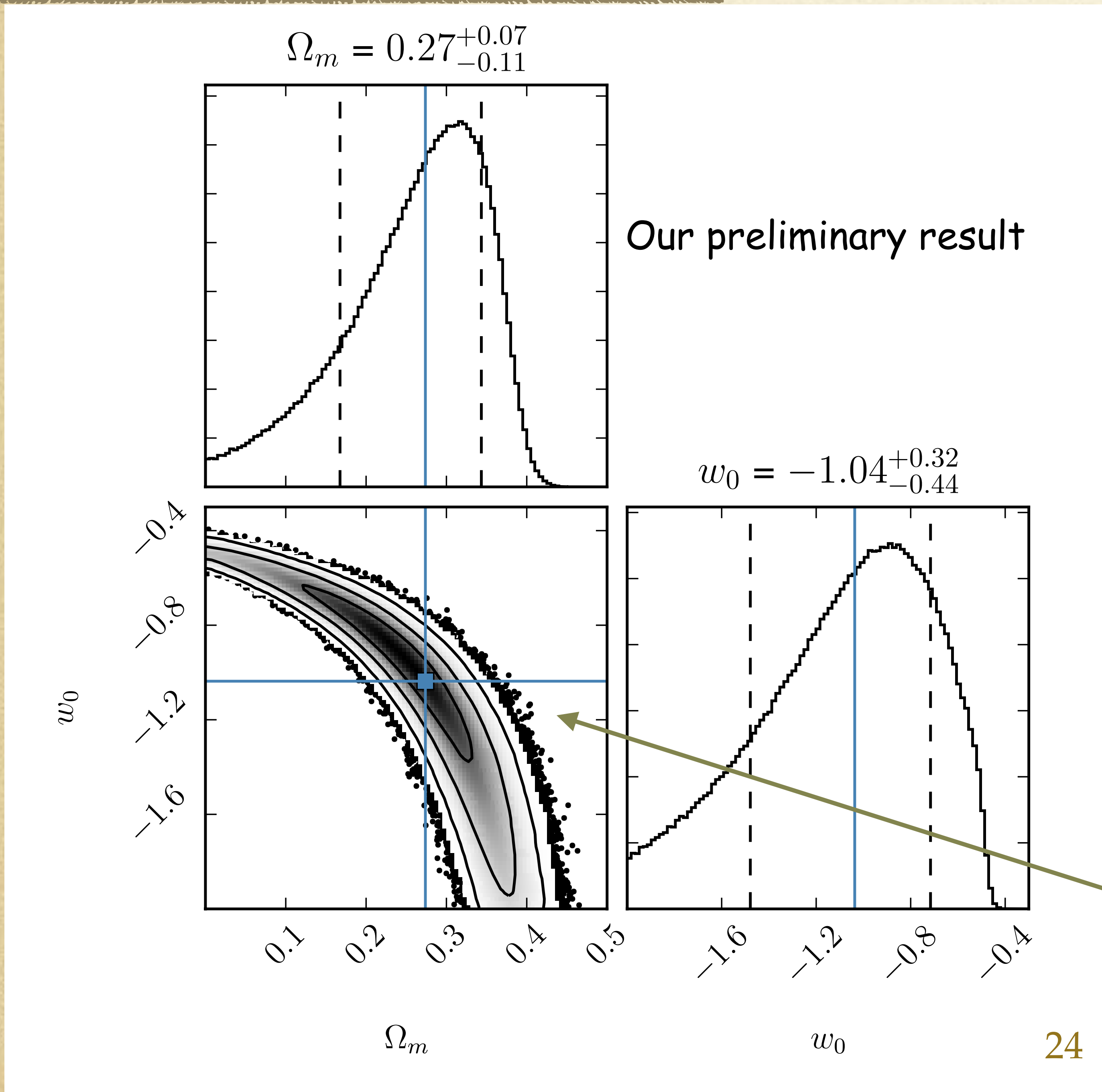
Our MCMC result for a flat universe ($\Omega_k = 0$) with H_0=74.3.

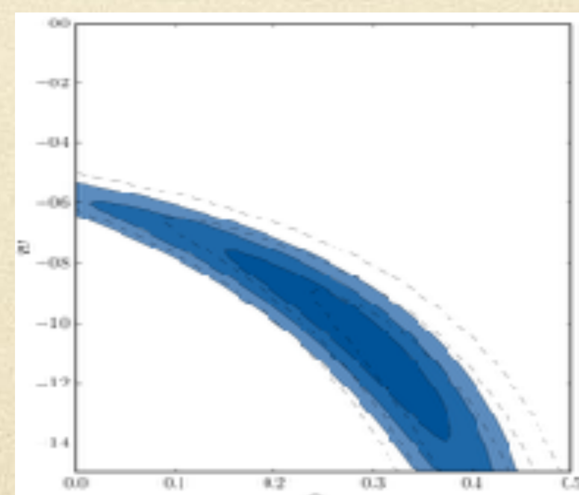
$\Omega_m = 0.27^{+0.07}_{-0.11}$ and $w = -1.04^{+0.32}_{-0.44}$ (statistical uncertainties only)

The sample has 109 local HIIG and 22 high z HIIG with high quality data from VLT-XShooter and KECK-MOSFIRE.

The Suzuki et al 2012 580 SNIa solution with statistical uncertainties only gives

$\Omega_m = 0.28^{+0.07}_{-0.09}$ and $w = -1.01^{+0.21}_{-0.23}$





Amanullah et al 2010 (dashed)
Suzuki et al 2012 (shadow)

(similar scale)

CONCLUSIONS I

- HIIG explore a range of high z ($1.5 < z < 3.5$) that is not available to other methods (SNIa and BAO). This range is crucial to study the evolution of the DE equation of state.

- Results are very promising. Cosmology with HIIG and GHIIR is becoming highly competitive. Needs more data and more work.

- The fact that our results are in line with SN, BAO and CMB implies that our basic assumptions are correct.

- We will learn more about massive star formation that in turn will allow a better distance estimator.

- Extension to $z>3.5$ depends on availability of instrumentation.

CONCLUSIONS II

Assuming a universal IMF in young SSC the application of the **L-σ** distance indicator gives values of the cosmological parameters H_0, Ω_m & w that are in excellent agreement with those of Concordance Cosmology.

This in turn allow to set limits on the evolution of the IMF. Any change in the slope of the IMF between z ~ 0 and z ~ 2.5 has to be less than ~0.06 at 1-σ level.

An homogenous sample selection is central to the results.