European Southern Observatory

The deaths of stars and the lives of galaxies

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elemental abundances on galaxies hosting SNIa fron SLOAN/SDSS

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MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Ciemat
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ESTALLIDOS NETWORK

0.Outline

1.Introduction

1.1.Supernova cosmology
1.2.SNe Ia luminosity and progenitor metallicity
1.3.SNe Ia luminosity and host galaxies general properties
1.4. Light Curve (LC) – Metallicity

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2.2.Ions distribution inside the nebula

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3.2.Final selection

4.Results

4.1.Empirical methods for abundances estimation
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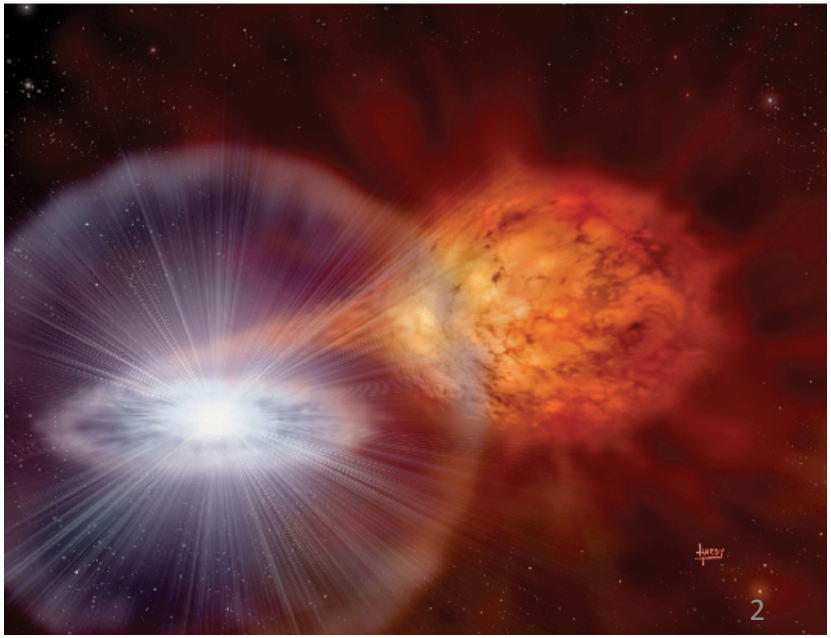
4.3.Hubble Diagram

5.Conclusions



Supernova cosmology is based on the well-known Hubble Diagram $d(SNe\ Ia) \Leftrightarrow z$

Their redshifts are determined from their spectra and the distances are given by the distance modulus $\mu = m - M$

Perlmuter et al. 1999
Riess et al. 1998

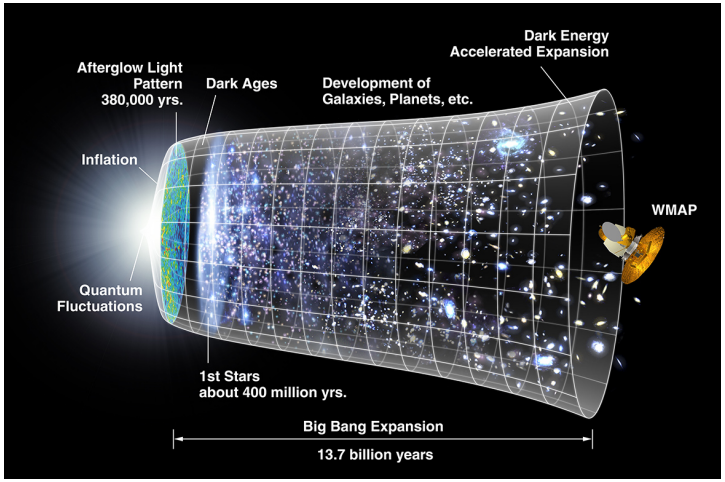
Standard-calibrated candles

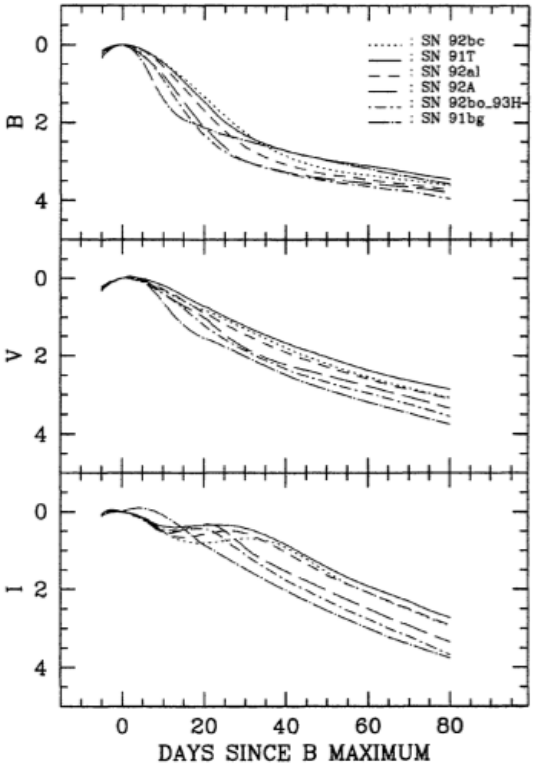
$$M = m - \alpha \Delta m_{15,B} + \beta C$$

Codes
SALT2, MLCS

Cosmological parameters

$$\Omega_\Lambda = 0.734$$
$$\Omega_M = 0.266$$





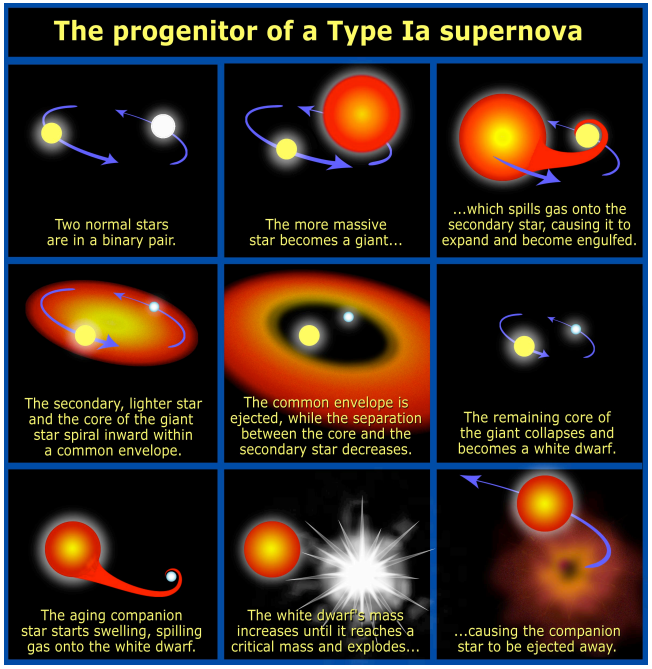
(Hamuy et al. 1996)

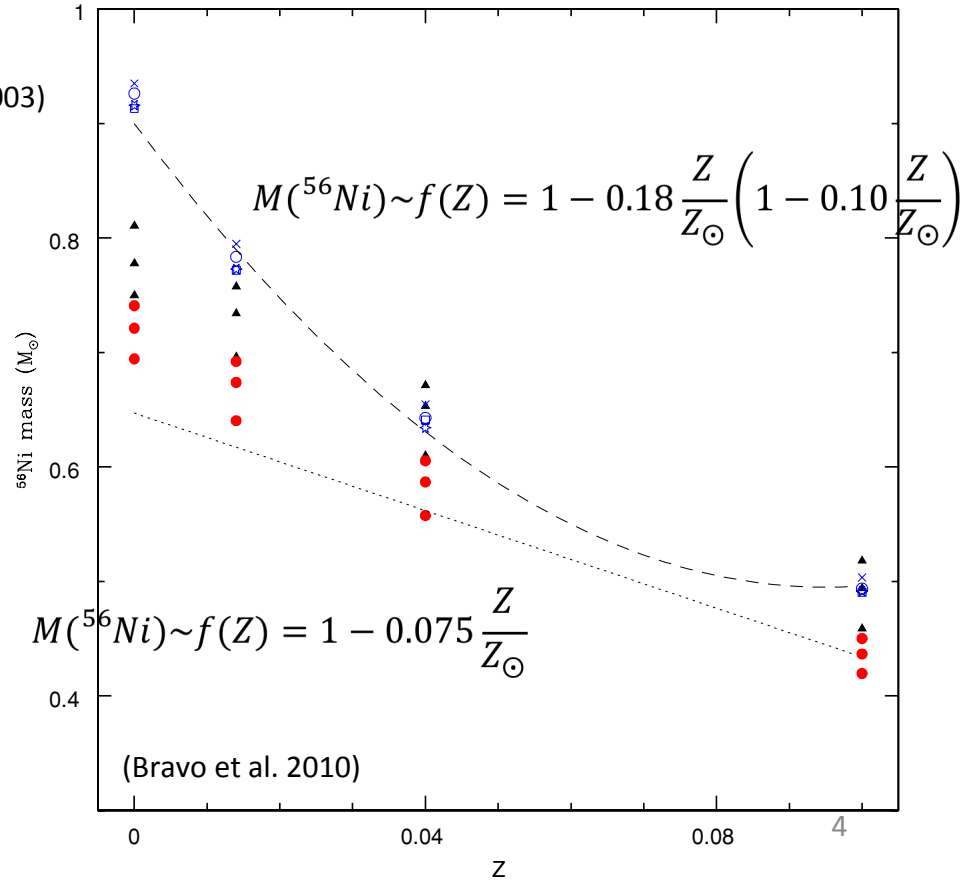
SNe Ia calibration on local objects whose host galaxies probably share solar or almost solar abundances.

May not be valid for high redshift objects

The metallicity dependence of the SNe Ia luminosity has been neglected so far. Systematics.

$$L = 2\times10^{43} M(^{56}Ni)\ \mathrm{erg\ s^{-1}}$$ (Timmes et al. 2003)





The ^{56}Ni depends on the burning densities and on the neutron excess or the proton-to-nucleon ratio

The proton-to-nucleon ratio depends on the abundance of elements with excess of neutrons, mainly ^{22}Ne and ^{56}Fe

^{22}Ne depends in turn on the CNO abundances

The maximum magnitude depends on the WD abundance of C, N, O an Fe

INITIAL METALLICITY OF THE PROGENITOR

$$M(^{56}Ni) \sim f(Z) = 1 - 0.075\frac{Z}{Z_\odot}$$

(Bravo et al. 2010)

$$M(^{56}Ni) \sim f(Z) = 1 - 0.18\frac{Z}{Z_\odot}\left(1 - 0.10\frac{Z}{Z_\odot}\right)$$

Look for dependences of the SN properties on the host galaxy properties (focused on global characteristics of the host)

Sullivan et al. (2006)	SNIa are brighter in massive hosts (metal-rich)
Neill et al. (2009)	Older hosts produce less-extincted SNe Ia
Howel et al. (2009)	more massive progenitors give rise to more luminous explosions
Hicken et al. (2009)	SN Ia in spiral hosts are intrinsically fainter
Lampeitl et al. (2010)	introduce the stellar mass of the host in the parametrization
D'Andrea et al. (2011)	SNe are 0.1 mag brighter in high-metallicity hosts
Konishi et al. (2011)	SNe in metal-rich hosts become brighter
Gupta et al. (2011)	older galaxies host SNe Ia that are brighter

Phillips et al. 1999 calibration

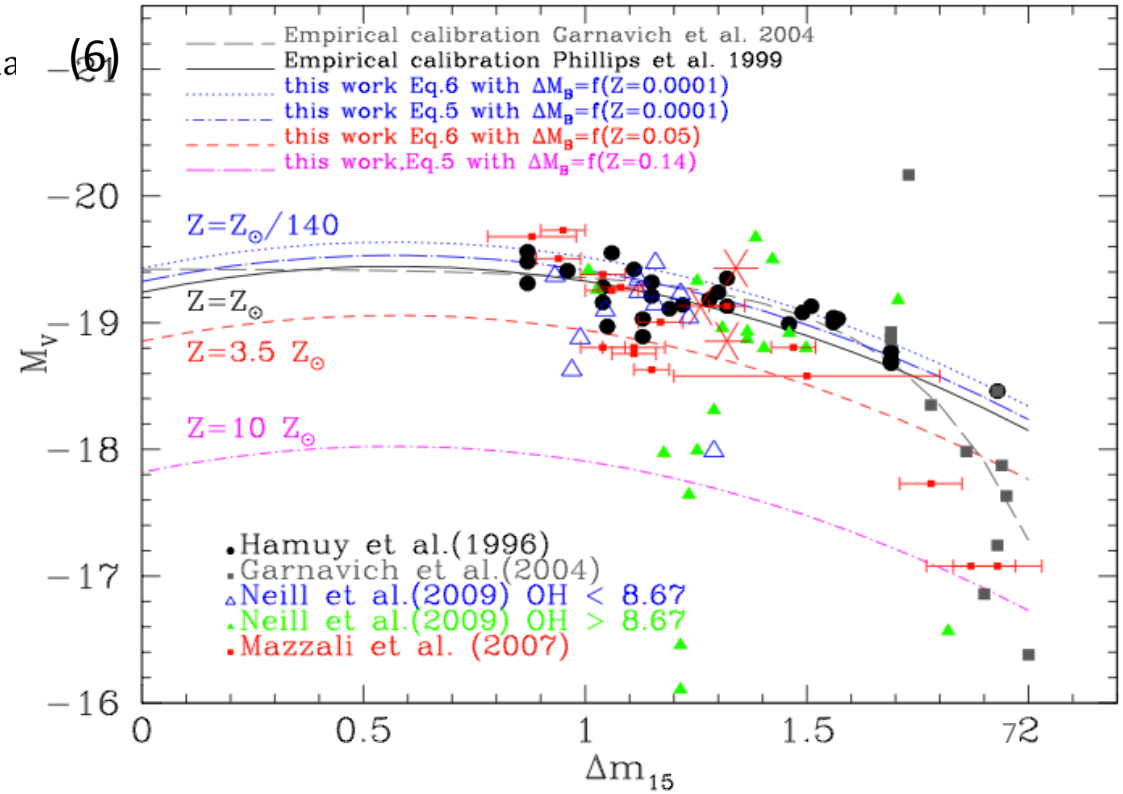
$$M_V(\Delta m_{15,B}) = -19.27 + 0.672(\Delta m_{15,B} - 1.1) + 0.633(\Delta m_{15,B} - 1.1)^2 \text{ mag} \quad (4)$$

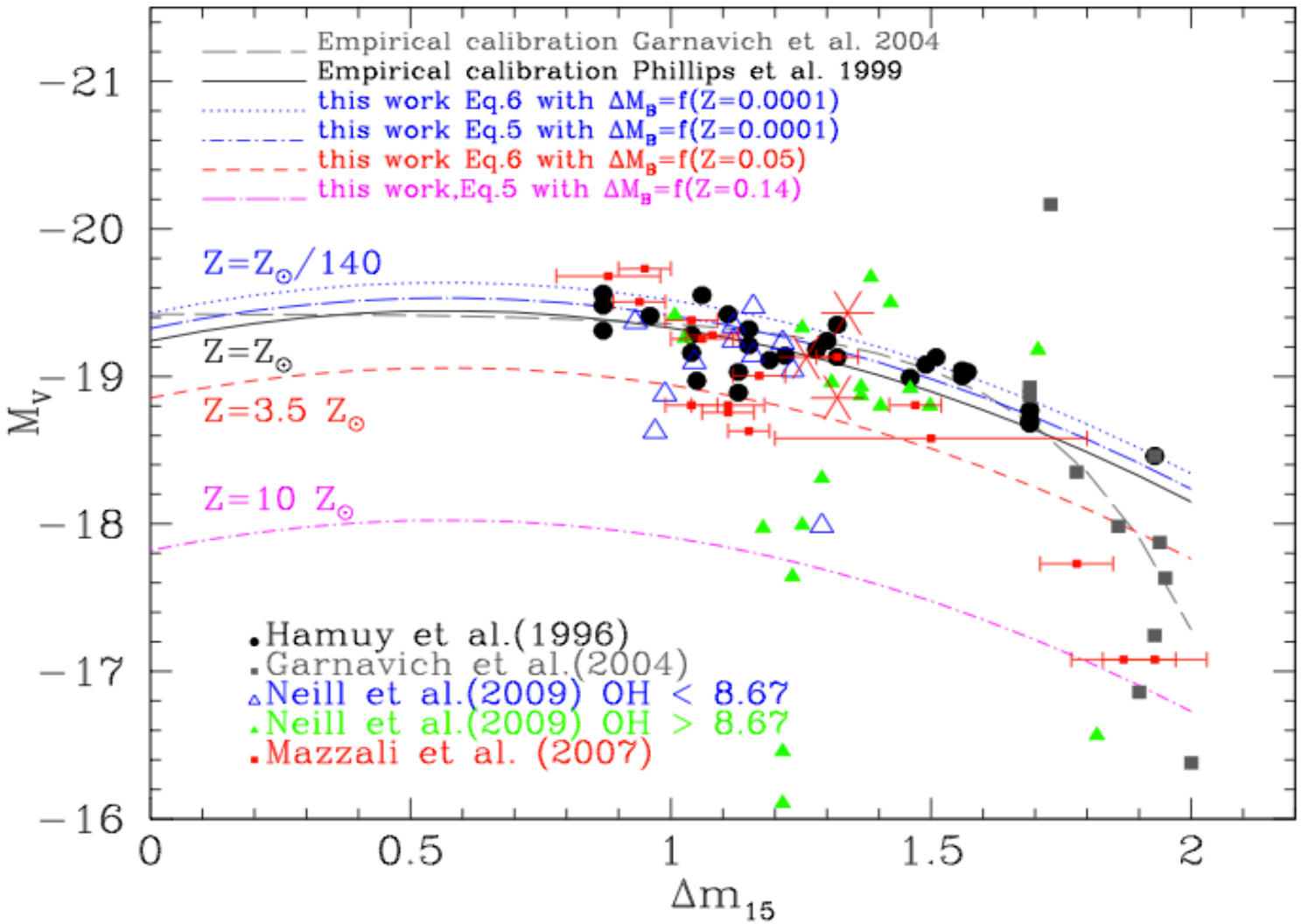
$$M_V(Z, \Delta m_{15,B}) = M_V(\Delta m_{15,B}) + \Delta M_V(Z) \text{ mag},$$

$$\Delta M_V(Z) = -2.5 \log\left[1 - 0.18\frac{Z}{Z_\odot}\left(1 - 0.010\frac{Z}{Z_\odot}\right)\right] - 0.191 \text{ mag}, \quad (7)$$

$$\Delta M_V(Z) = -2.5 \log\left(1 - 0.075\frac{Z}{Z_\odot}\right) - 0.0846 \text{ ma} \quad (6)$$

Calibration curves for different metallicities following Equations 4, 6 and 7.




Empirical calibration Garnavich et al. 2004
Empirical calibration Phillips et al. 1999
this work Eq.6 with ΔM_B=f(Z=0.0001)
this work Eq.5 with ΔM_B=f(Z=0.0001)
this work Eq.6 with ΔM_B=f(Z=0.05)
this work,Eq.5 with ΔM_B=f(Z=0.14)
Z=Z⊙/140
Z=Z⊙
Z=3.5 Z⊙
Z=10 Z⊙
Hamuy et al.(1996)
Garnavich et al.(2004)
Neill et al.(2009) OH < 8.67
Neill et al.(2009) OH > 8.67
Mazzali et al. (2007)
M_V
Δm_15
−21
−20
−19
−18
−17
−16
0
0.5
1
1.5
2

HII region: ionized gas volume by a hot star (or stellar cluster) with effective temperatures $T_{eff} > 25000 - 50000\ K$.

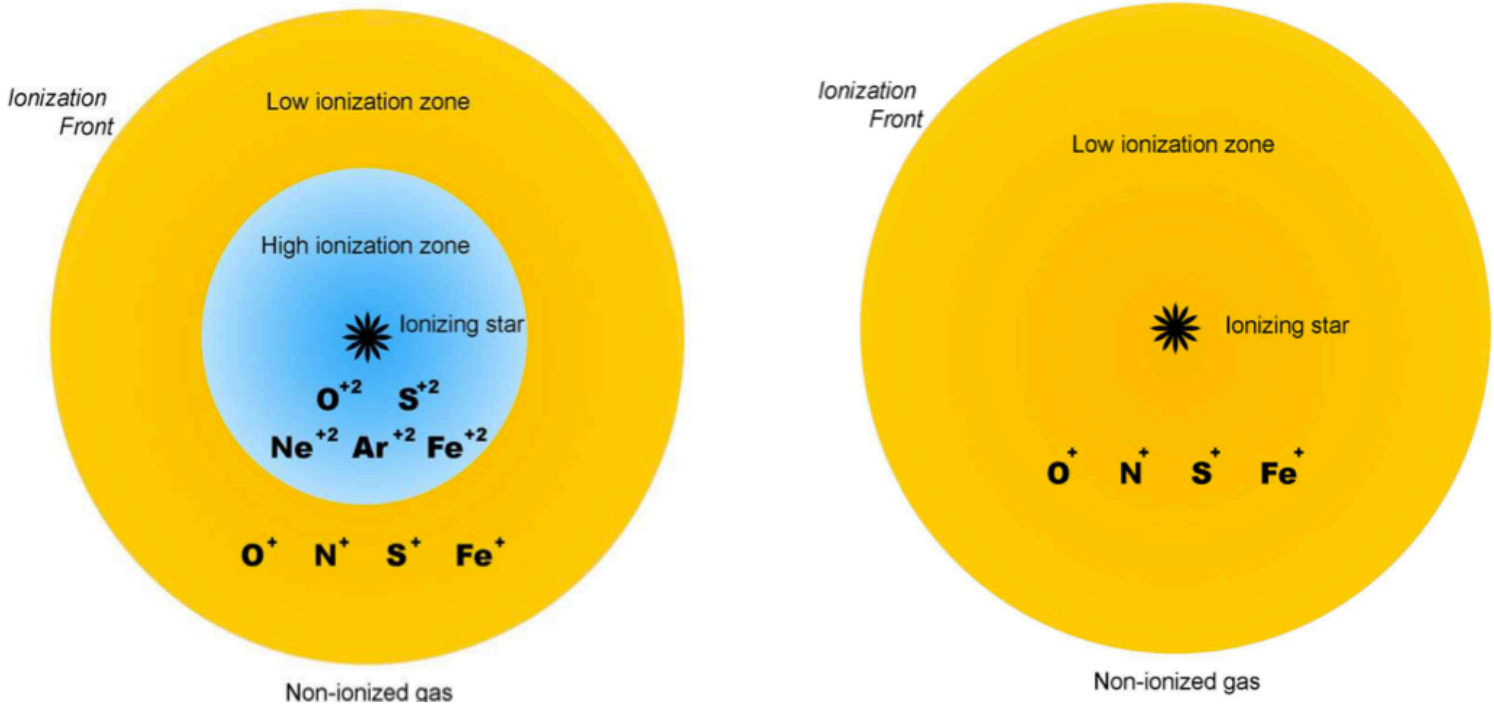
Ionized gas spectrum analysis

Chemical abundances.
High luminosity, high superficial brighness, and emission-line spectrum allow direct observation in far objects if the cluster is massive and brilliant.

Orion nebula

Elements: He, Ne, Ar, O, N, S…

Planetary nebulae, emission nebulae aroundWolf-Rayet, supernovae remmants, AGNs…

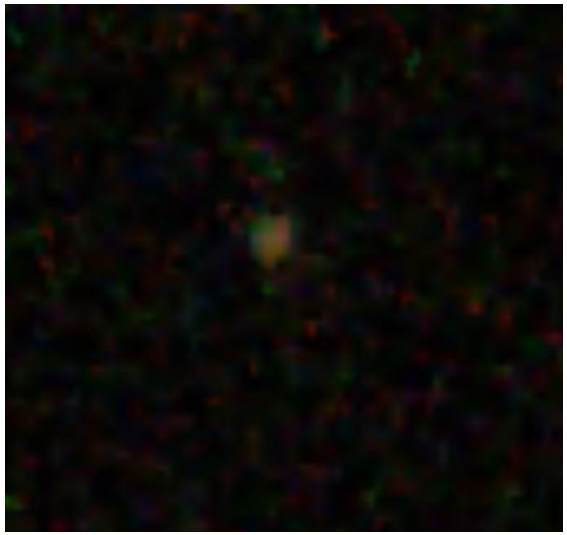


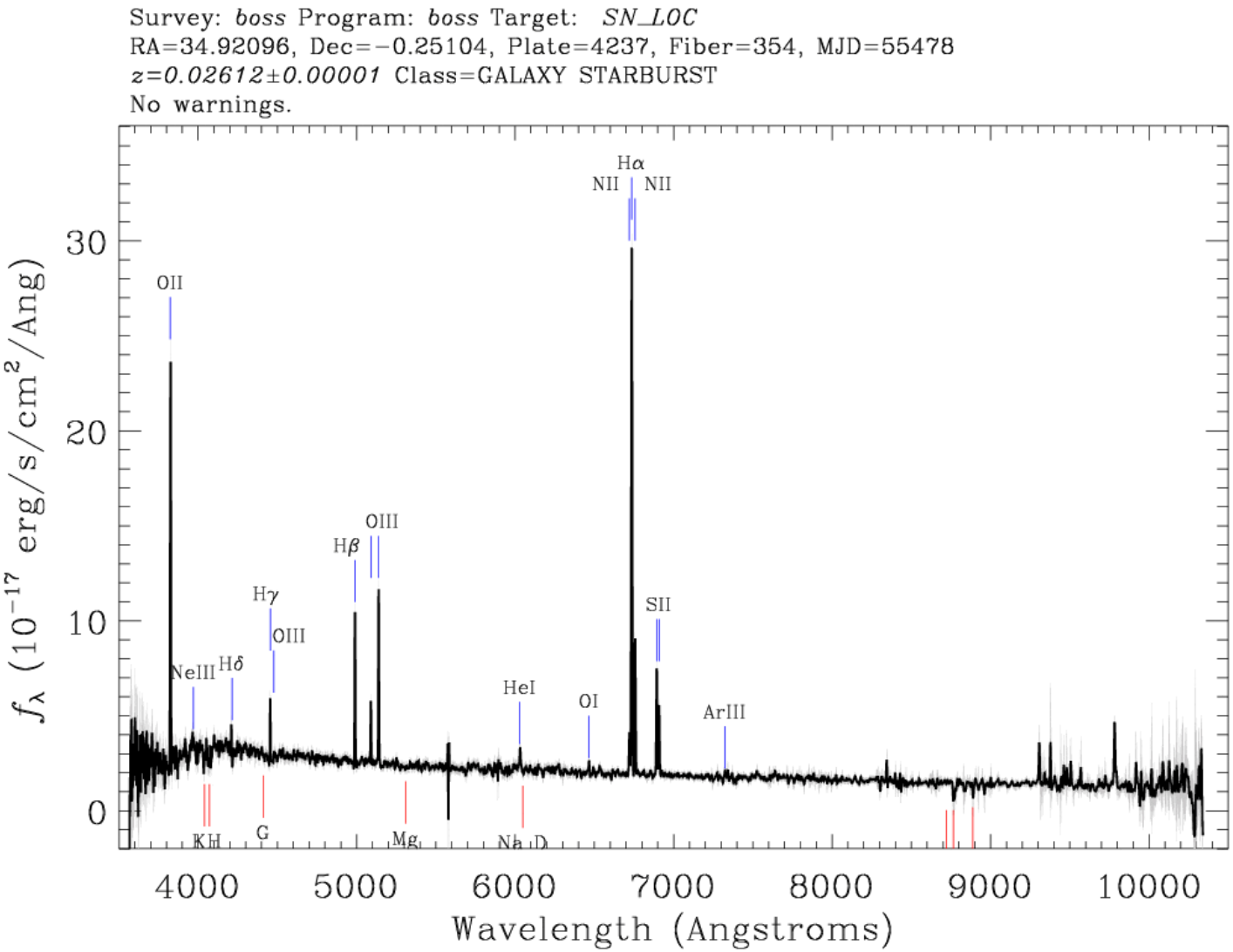
There is not only one star ionizing. Actually, there are stellar clusters. This picture is only a simplification. Left picture, hot star, where second ionizations are produced; right picture, temperature is not high enough to be high ionization zone.

Galaxies in Konishi et al. (2011). From 115 initial, 40 selected.

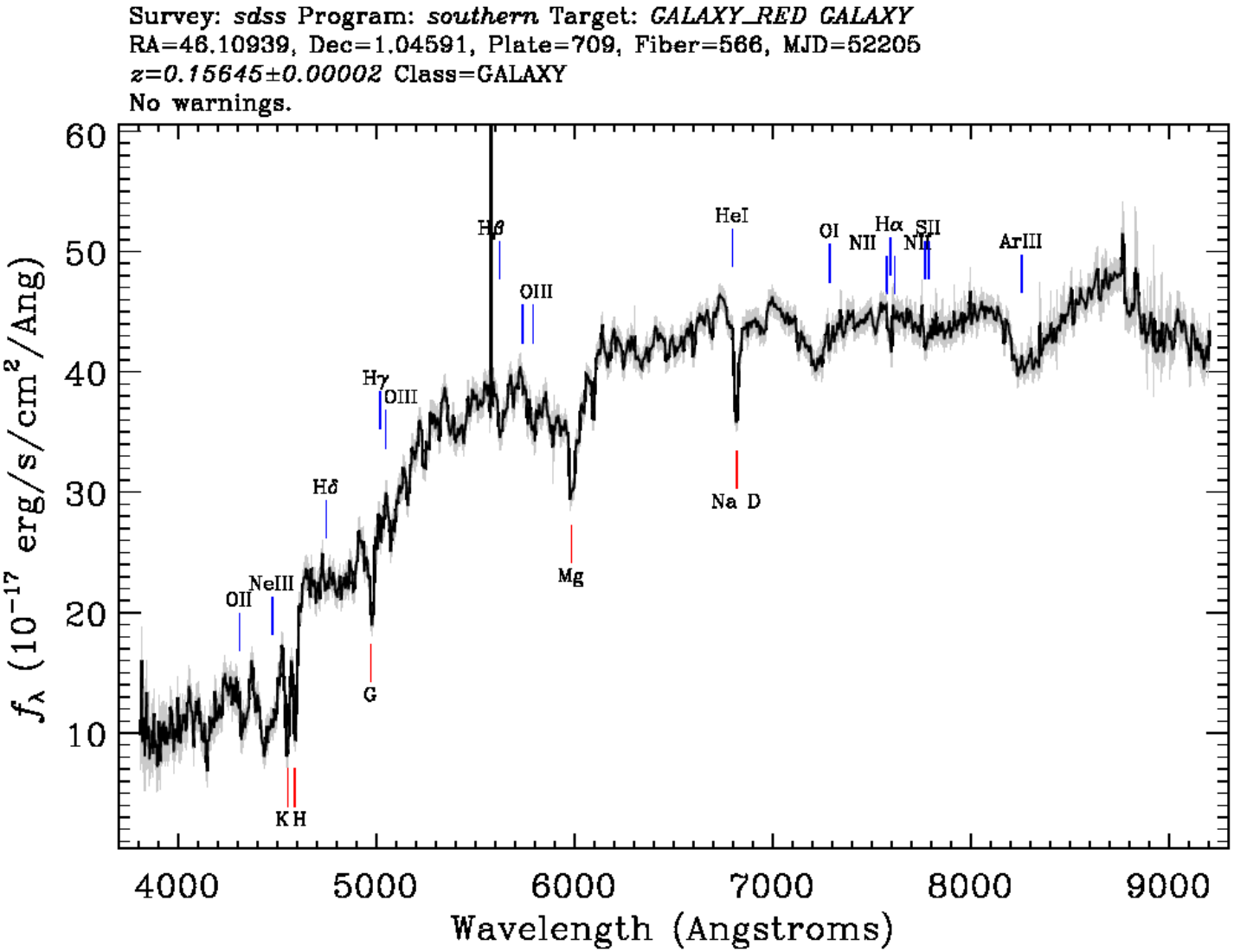
Criteria: $\Delta m_{15,B} < 1.90$, good SNR for 12 + log(O/H) and E(B–V). Diagnostic diagram.

SN	IAU	RA	DEC	SN	IAU	RA	DEC
SN 1580	2005 fb	45,32495	-0,64510	SN 15467	...	0,02009	-0,17735
SN 2561	2005 fv	46,34430	0,85972	SN 16069	2006 nd	1,24505	-1,00693
SN 2992	2005 gp	55,49731	-0,78294	SN 17117	2006 qm	0,60192	-0,79517
SN 3592	2005 gb	19,05289	0,79061	SN 17134	2006 rz	4,56786	-0,11012
SN 3901	2005 ho	14,85049	0,00266	SN 17176	2007 ia	34,40283	0,61326
SN 5966	2005 it	16,19056	0,51326	SN 17280	2007 hz	55,79183	0,10401
SN 6057	2005 if	52,55368	-0,97448	SN 17366	2007 jt	15,78499	-1,03117
SN 7876	2005 ir	19,18279	0,79361	SN 17497	2007 jg	37,13650	-1,04286
SN 8151	2005 hk	6,95722	-1,19997	SN 17784	2007 jd	52,46180	0,05444
SN 10096	2005 lj	29,42965	-0,17924	SN 17880	2007 kq	44,97361	1,16003
SN 10805	2005 ku	44,92784	-0,01356	SN 18030	2007 lc	4,93321	-0,40009
SN 12778	2006 fs	17,49564	0,40859	SN 18612	2007 ma	12,28801	0,59660
SN 12856	2006 fl	32,86538	0,75559	SN 18697	2007 mh	11,22420	-0,99687
SN 12950	2006 fy	51,66727	-0,84061	SN 18855	2007 mn	48,63386	0,26887
SN 13072	2006 fi	4,96065	0,02368	SN 19155	2007 nj	31,26481	0,17512
SN 13254	2006 gx	2,05870	-0,34681	SN 19353	2007 ok	43,11326	0,25174
SN 13610	2006 hd	6,01425	0,72551	SN 19616	2007 ou	37,09966	0,18600
SN 15136	2006 ju	1,16219	-0,71793	SN 19626	2007 pt	35,92775	-0,82647
SN 15234	2006 kd	6,95808	0,82859	SN 19969	2007 om	31,90982	-0,32403
SN 15421	2006 kw	3,74128	0,60272	SN 20528	2007 qr	43,12132	-1,13946

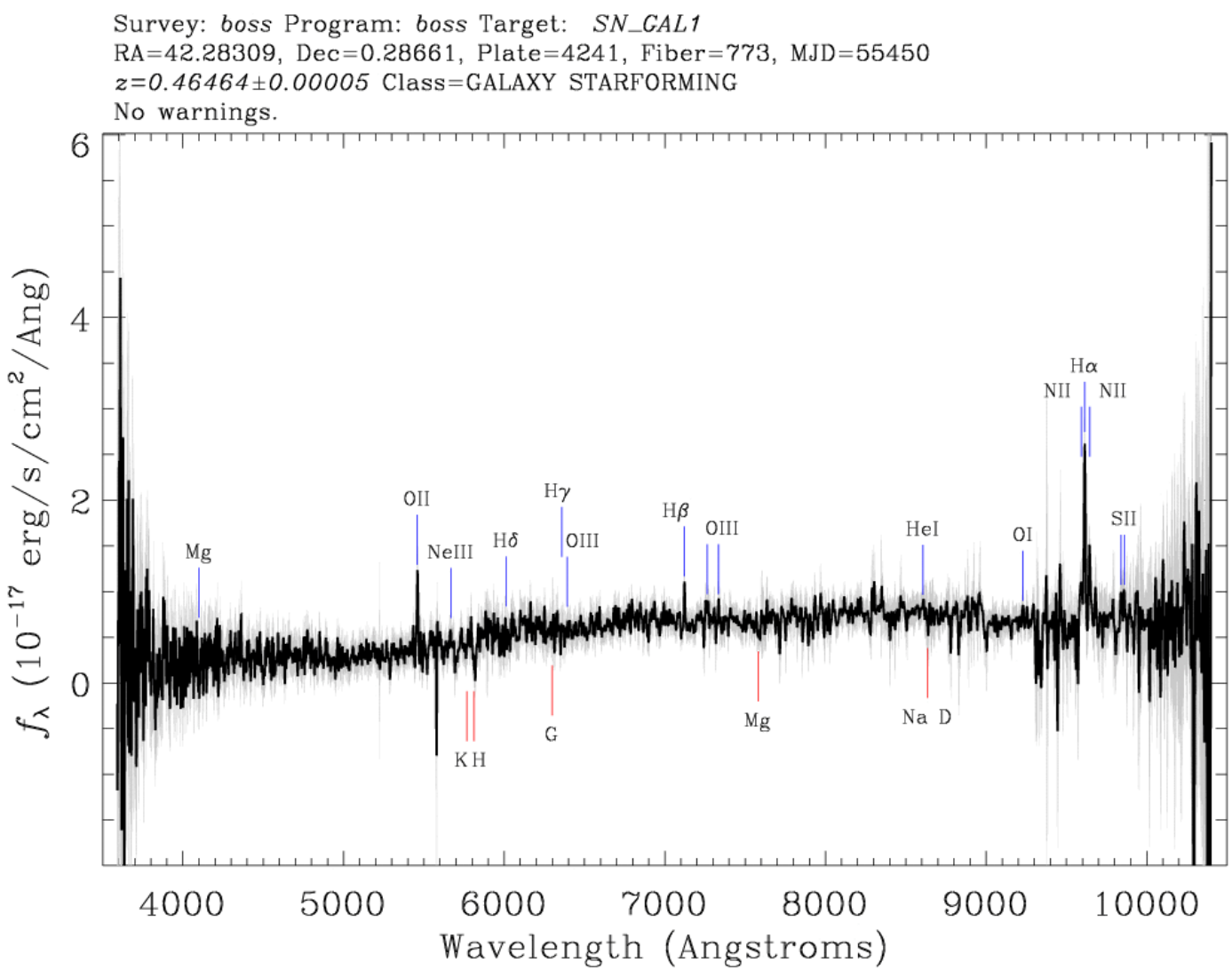



Survey: boss Program: boss Target: SN_LOC
RA=34.92096, Dec=−0.25104, Plate=4237, Fiber=354, MJD=55478
z=0.02612±0.00001 Class=GALAXY STARBURST
No warnings.
OII
NeIII
Hδ
Hγ
OIII
Hβ
OIII
HeI
OI
Hα
NII
NII
SII
ArIII
K
H
G
Mg
Na
D
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)
0
10
20
30
4000
5000
6000
7000
8000
9000
10000

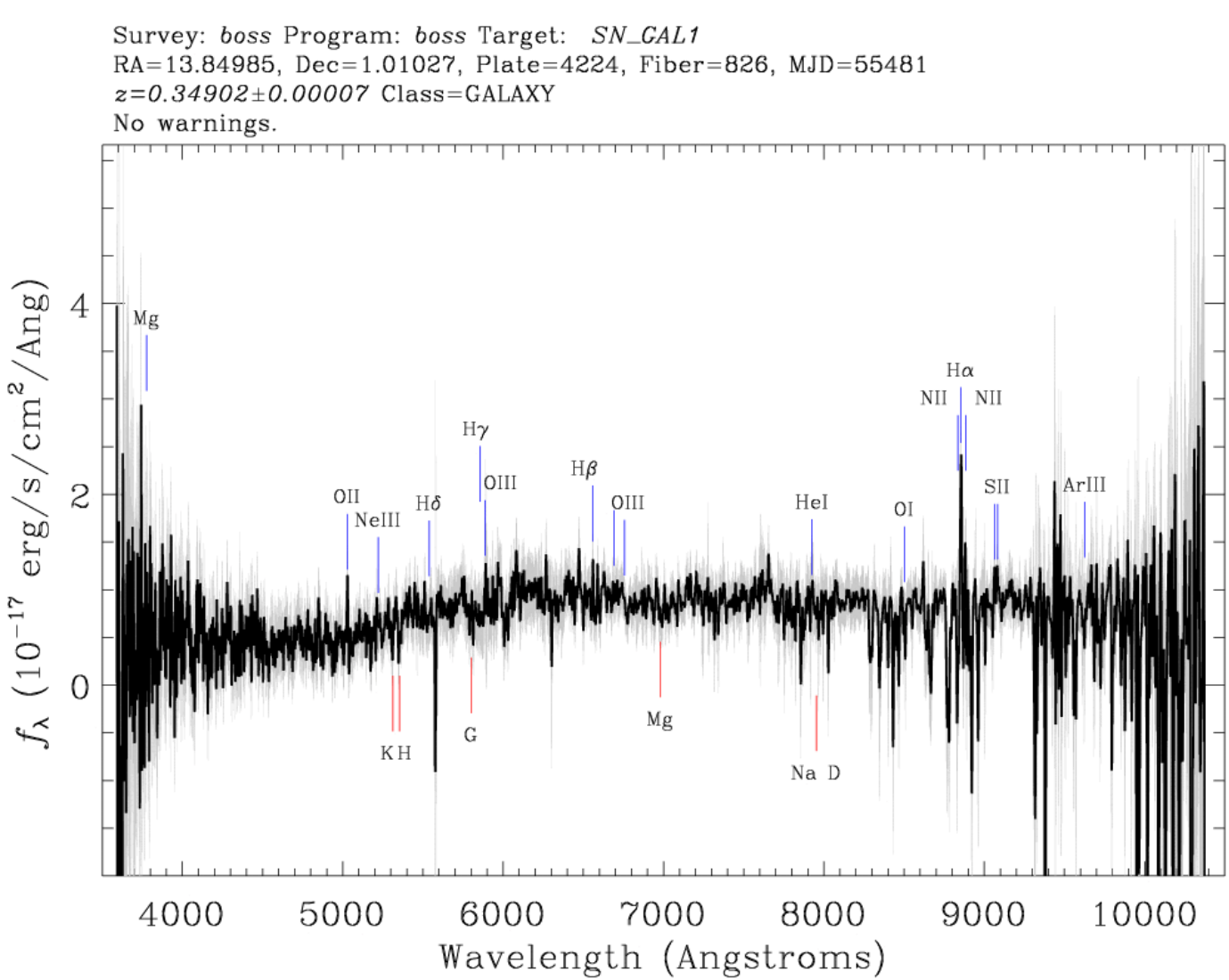
Spirals…


Survey: sdss Program: southern Target: GALAXY_RED GALAXY
RA=46.10939, Dec=1.04591, Plate=709, Fiber=566, MJD=52205
z=0.15645±0.00002 Class=GALAXY
No warnings.
Hβ
OIII
HeI
OI
NII
Hα
SII
NII
ArIII
Hγ
OIII
Hδ
Na D
Mg
OII
NeIII
G
K H
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)
60
50
40
30
20
10
4000
5000
6000
7000
8000
9000

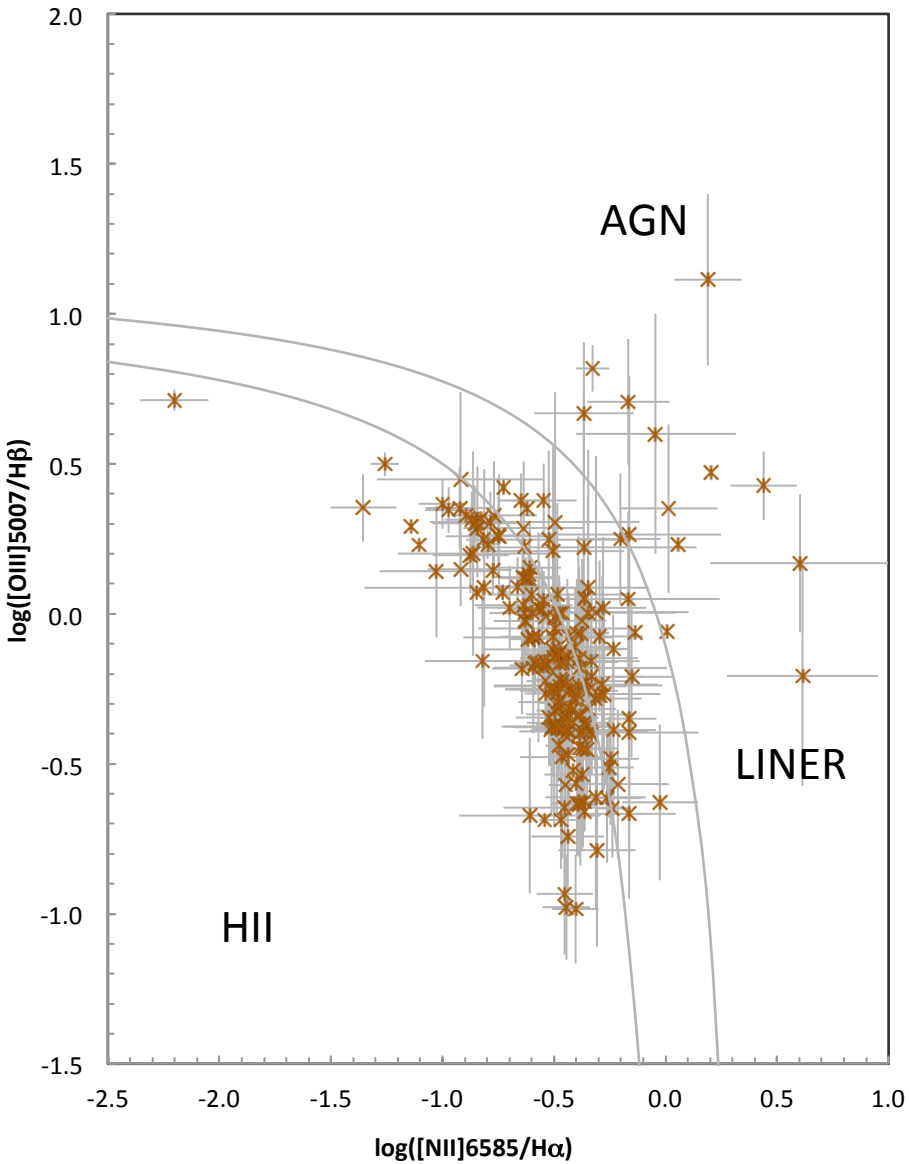
Elliptical…



High redshitf…


Survey: boss Program: boss Target: SN_CAL1
RA=13.84985, Dec=1.01027, Plate=4224, Fiber=826, MJD=55481
z=0.34902±0.00007 Class=GALAXY
No warnings.
Mg
OII
NeIII
Hδ
Hγ
OIII
Hβ
OIII
HeI
OI
Hα
NII
NII
SII
ArIII
KH
G
Mg
Na D
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)
4000
5000
6000
7000
8000
9000
10000
0
2
4

Trash…



Diagnostic diagram.

Eliminate LINERs and AGNs contributions, we are only interested in HII regions.

Oxygen abundance

Direct method. Auroral emission lines [OIII] λ4363. Electronic temperature.

Empirical calibrations. Based in part on photoionization models and partially on on the observational trends of abundances with intensities.

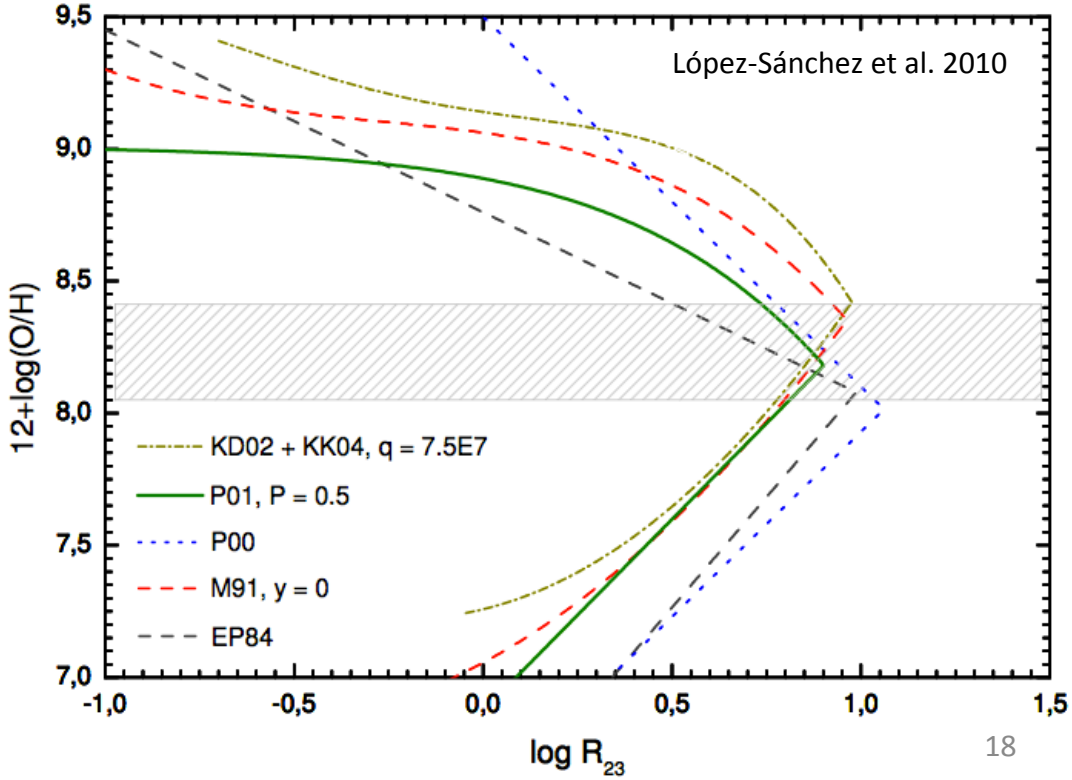
Brilliant oxygen lines,
Reliable calibrations

Parameters

$$R_{23} = R_2 + R_3$$

$$R_3 = \frac{I([OIII])4959\lambda + I([OIII])5007\lambda}{H\beta}$$

$$R_2 = \frac{I([OII])3727\lambda}{H\beta}$$



Calibrations from Pilyugin (2001) using parameter R_{23}

$$12 + \log(O/H)_{up} = \frac{R_{23} + 54.2 + 59.45P + 7.31P^2}{6.01 + 6.71P + 0.371P^2 + 0.243R_{23}}$$

High metallicity

$$12 + \log(O/H)_{low} = 6.35 + 1.45 \log R_{23} - 1.74 \log P$$

Low metallicity

Other parameters…

N2

$$N2 = \log \frac{I([NII])4583\lambda}{H\alpha}$$

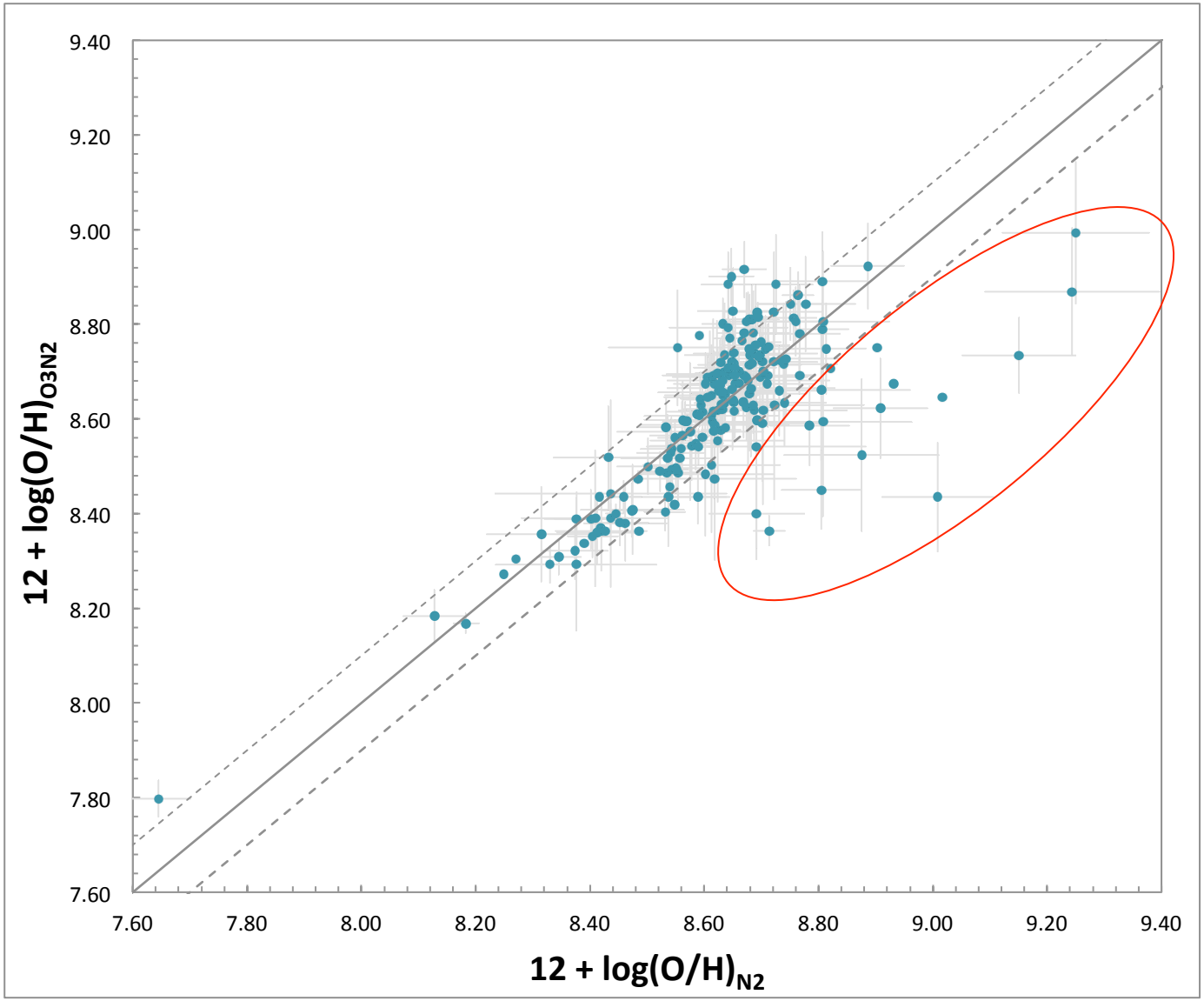
O3N2

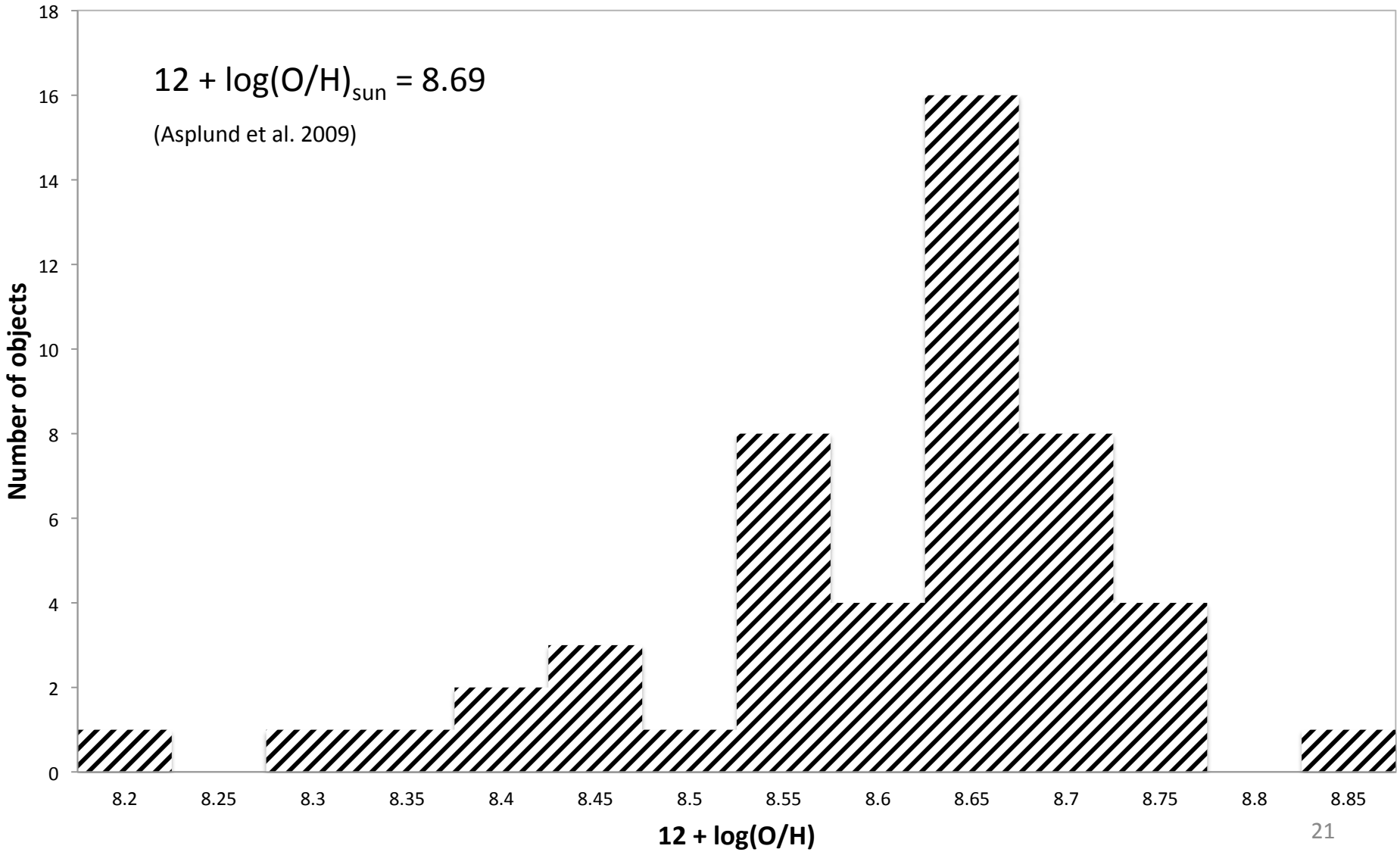
$$O3N2 = \log \frac{[OIII]5007\lambda/H\beta}{[NII]4863\lambda/H\alpha}$$

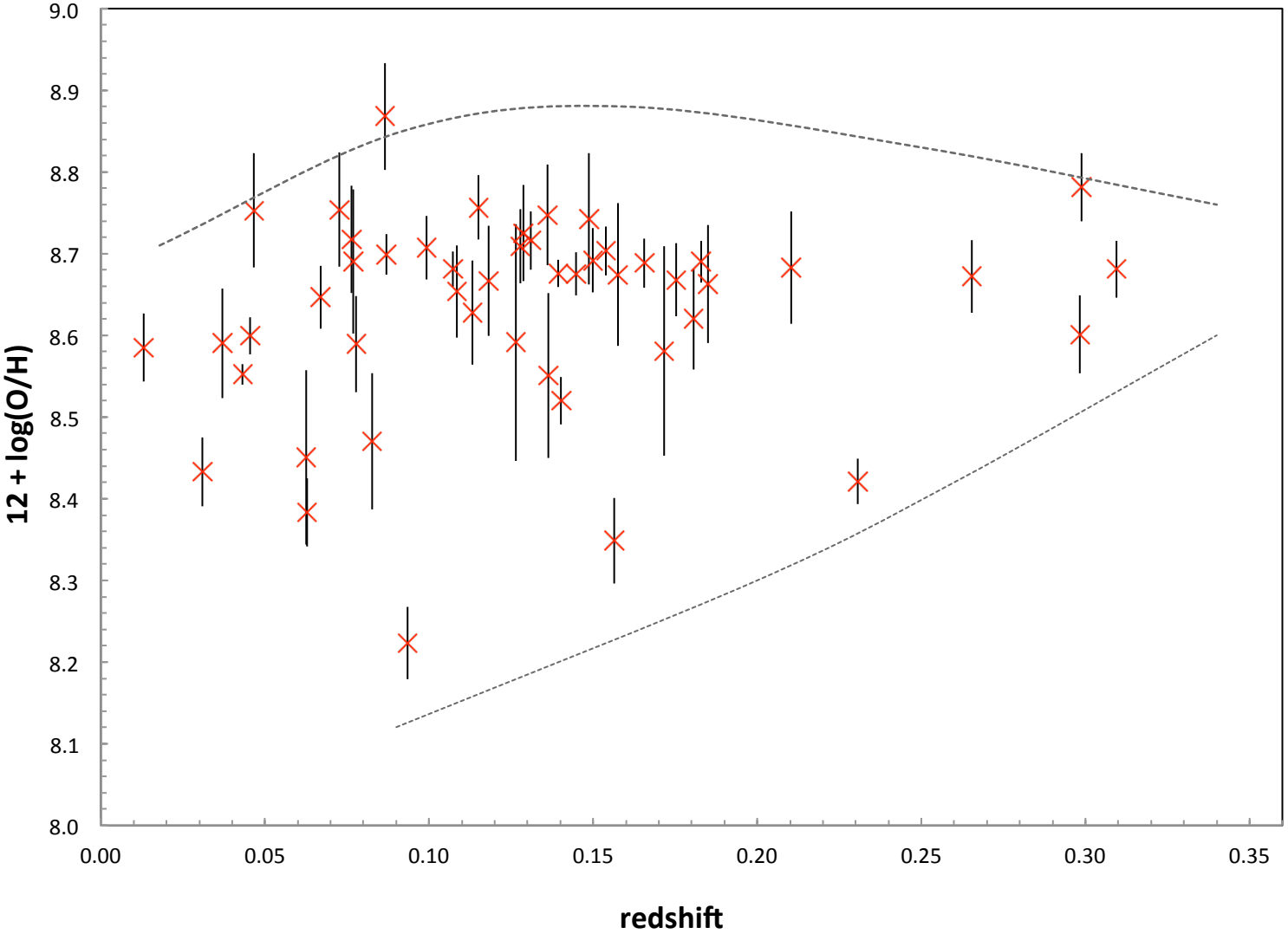
And calibrations proposed by Pettini & Pagel (2004)

$$12 + \log(O/H)_{N2} = 8.90 + 0.57N2$$

$$12 + \log(O/H)_{O3N2} = 8.73 - 0.32O3N2$$


9.40
9.20
9.00
8.80
8.60
8.40
8.20
8.00
7.80
7.60
12 + log(O/H)O3N2
7.60
7.80
8.00
8.20
8.40
8.60
8.80
9.00
9.20
9.40
12 + log(O/H)N2


$12 + \log(O/H)_{sun} = 8.69$
(Asplund et al. 2009)
Number of objects
0
2
4
6
8
10
12
14
16
18
8.2
8.25
8.3
8.35
8.4
8.45
8.5
8.55
8.6
8.65
8.7
8.75
8.8
8.85
12 + log(O/H)

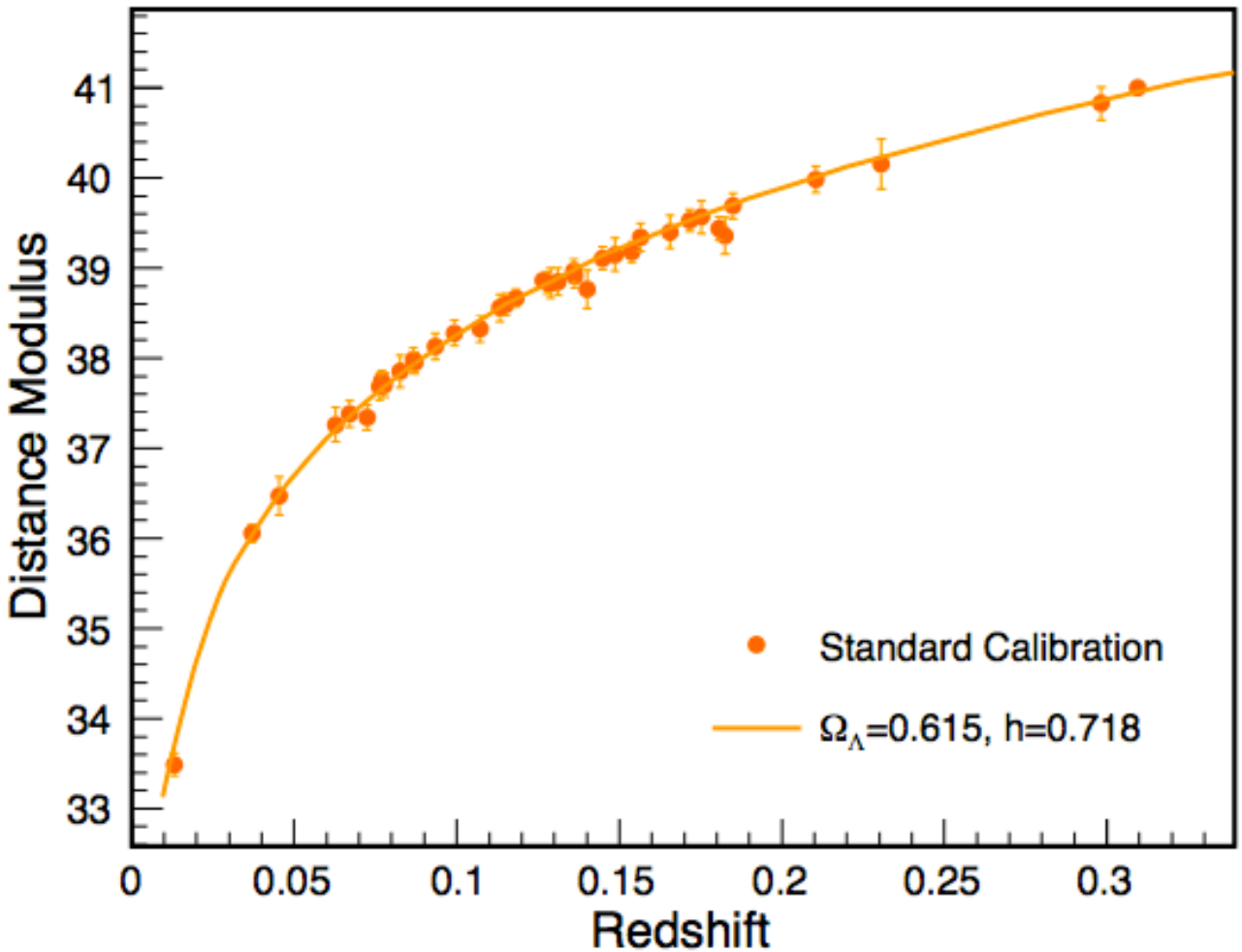


At high redshift we do not observe low metallicities.

Observational bias?

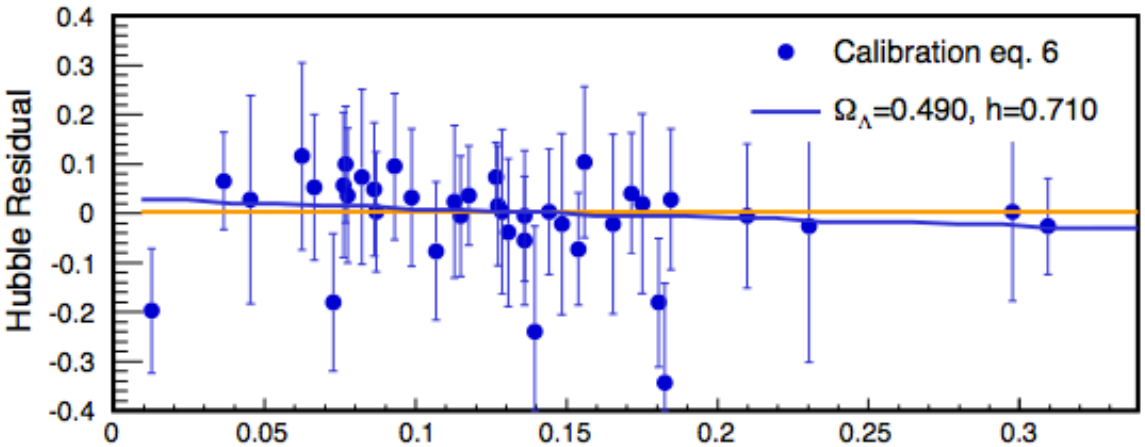
Previous work

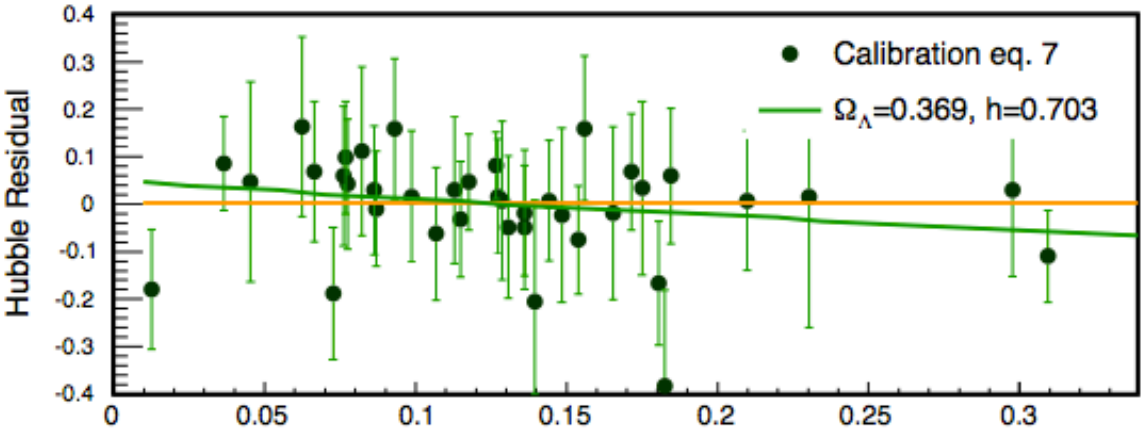
Hubble Diagram including only 40 SNe Ia



$$\Omega_\Lambda + \Omega_M = 1$$

M computed without considering any metallicity correction.



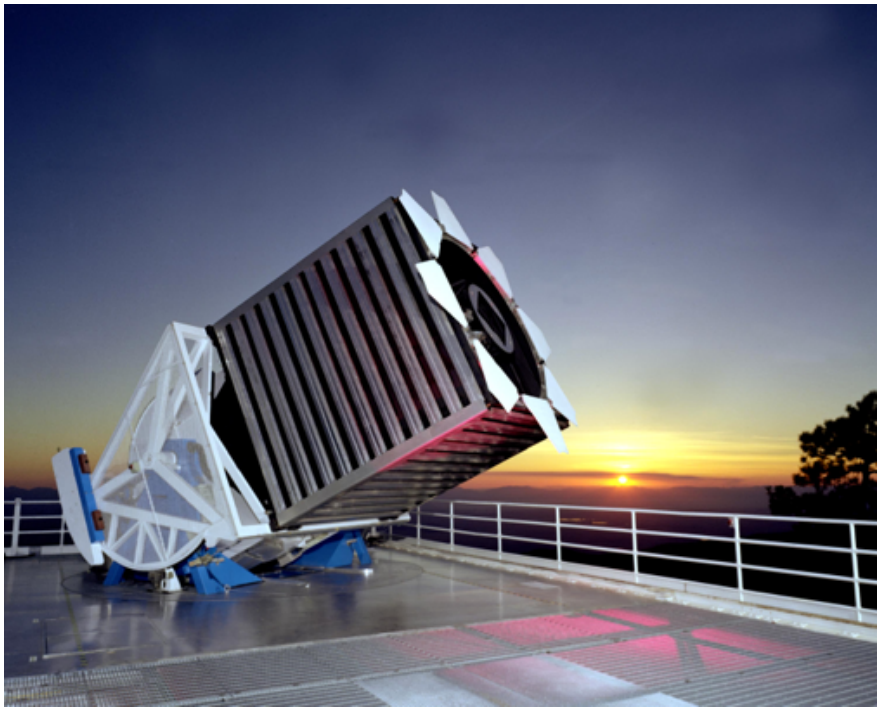


Both panels do consider a z dependence.

Orange continuous line is the best cosmological model obtained for SN Ia without correction.

Blue and green lines represent Hubble-law residuals with respect to the standard calibration.

SDSS-II SUPERNOVA SURVEY



2.5m telescope located at Apache Point Observatoy (APO) in Sunspot, New Mexico.

Data between 2005 and 2007.

z ~ 0.05 – 0.45

~1300 SN Ia (>500 spectroscopilally confirmed and >700 photometrically determined with host galaxy z_{spec})

724 have host galaxy spectra in DR9 and good LC fit.

330 has been selected to calculate oxygen abundances

- Consistent abundances with empirical methods without having auroral lines .
- Spectra revised carefully one by one.
- AGNs and LINERs are out of our final selection using diagnostic diagrams.
- Obtained abundances within solar order. Possible selection effect. Observational bias.
- Oxygen abundances from host galaxies and simulations to claculate the dependence on the metallicity for LC.
- Considering this dependence on metallicity, the cosmological models would have lower values of Ω_Λ than those derived when the metallicity is neglected.
- The effect of the metallicity could be more important for $z > 0.4$, due to the chemical enrichment of the universe and to larger differences between cosmological models.
- Is essential to take into account the dependence on metallicity in the Sne Ia absolute magnitude calculations.

Complete the sample by adding galaxies

Local Universe using 4.2m WHT at Roque de los Muchachos, La palma

High redshift objetcs z = 0.4 – 1.5…?? Using GTC at Roque de los Muchachos, La Palma

THANK YOU!

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