PROPERTIES OF II Zw 40 AS DERIVED FROM PHOTOIONIZATION MODELS

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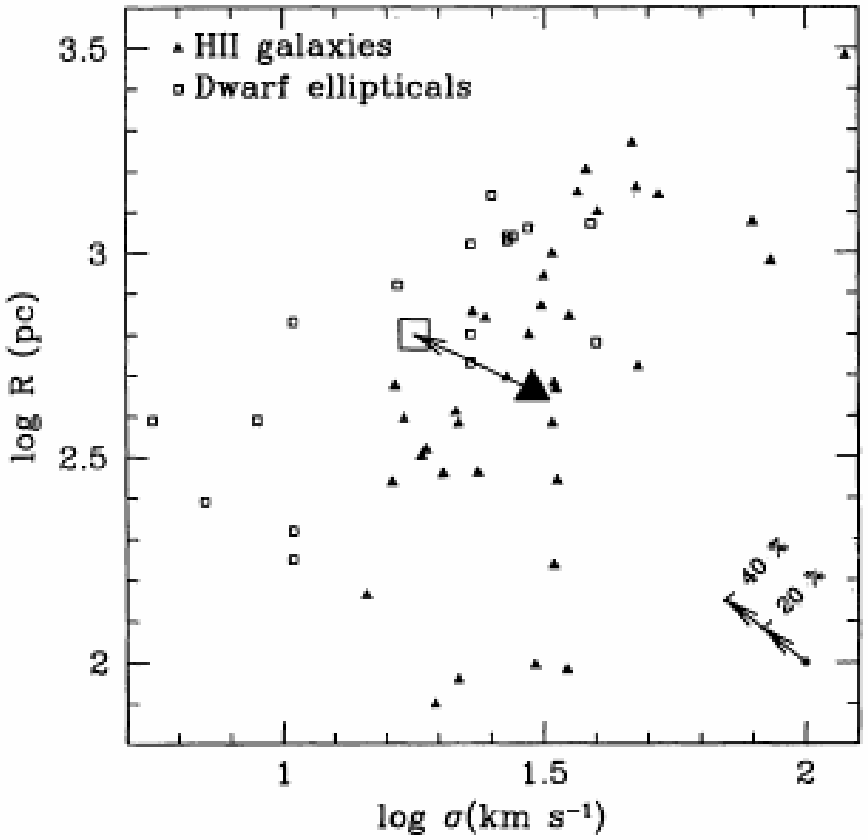
Granada. 26-28 January. Second workshop of the coordinated project
"Estallidos de formación estelar en galaxias"

Some of the properties of the HII galaxies as a part of the larger set of Blue Compact Galaxies (BCGs)… (let me remind you some of them) :

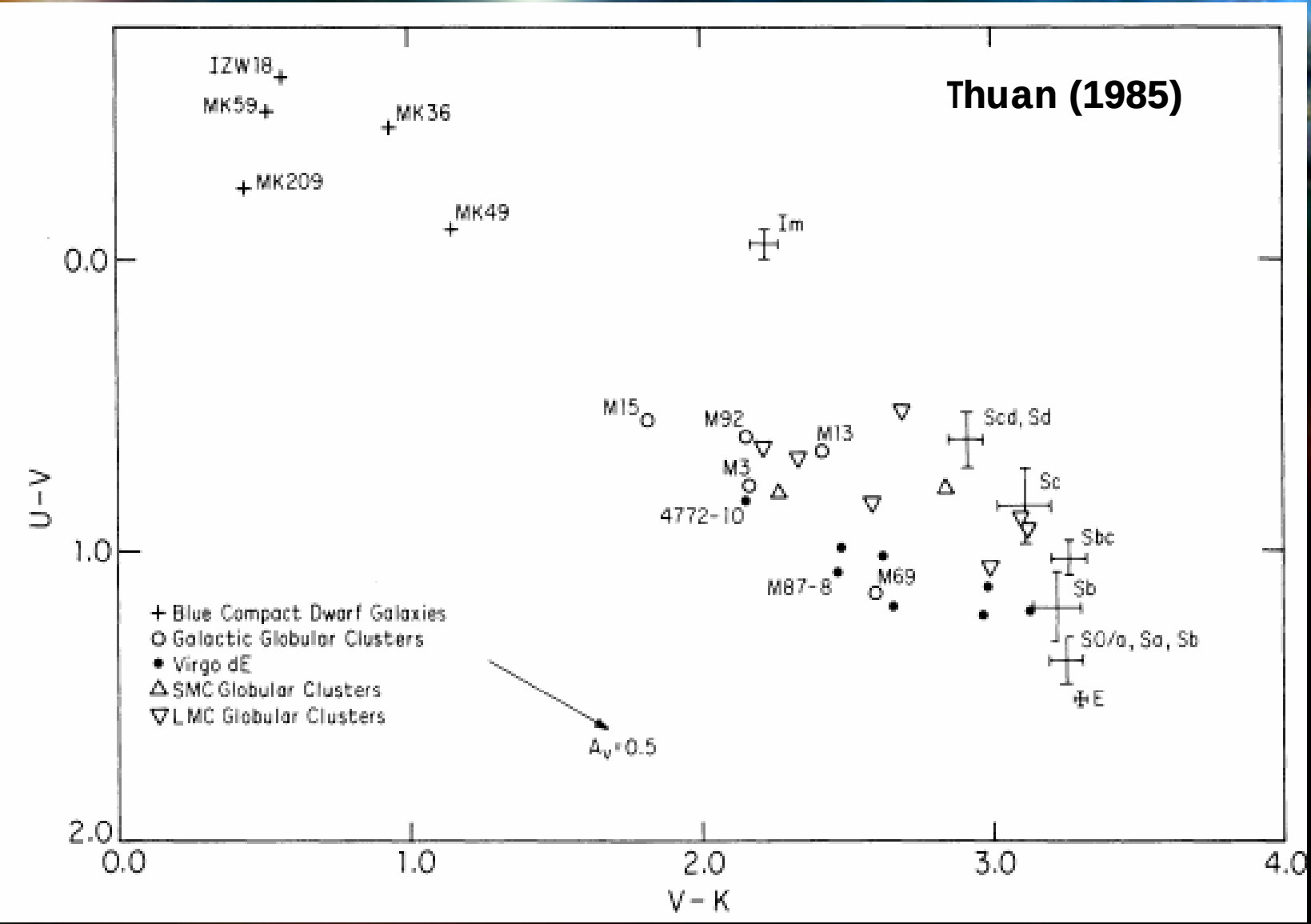
- ✦Compact aspect (Haro, 1956; Zwicky, 1960)
- ✦Prominent emission lines (Sargent & Searle, 1970)
- ✦Low metallicites as deduced from nebular analysis ($Z_\odot/50 < Z < Z_\odot/3$; Kunth & Sargent, 1986)
- ✦Intense blue color ($M_B > -18.8$; Papaderos et al. 1995, 1996)
- ✦Low content of molecular hydrogen ($M(H_2)/M(HI) \approx 0.01$; Sage et al. 1992)

… make them very suitable in order to answer some open questions about …

… the existence of an evolutionary link with elliptical and primaeval dwarfs,

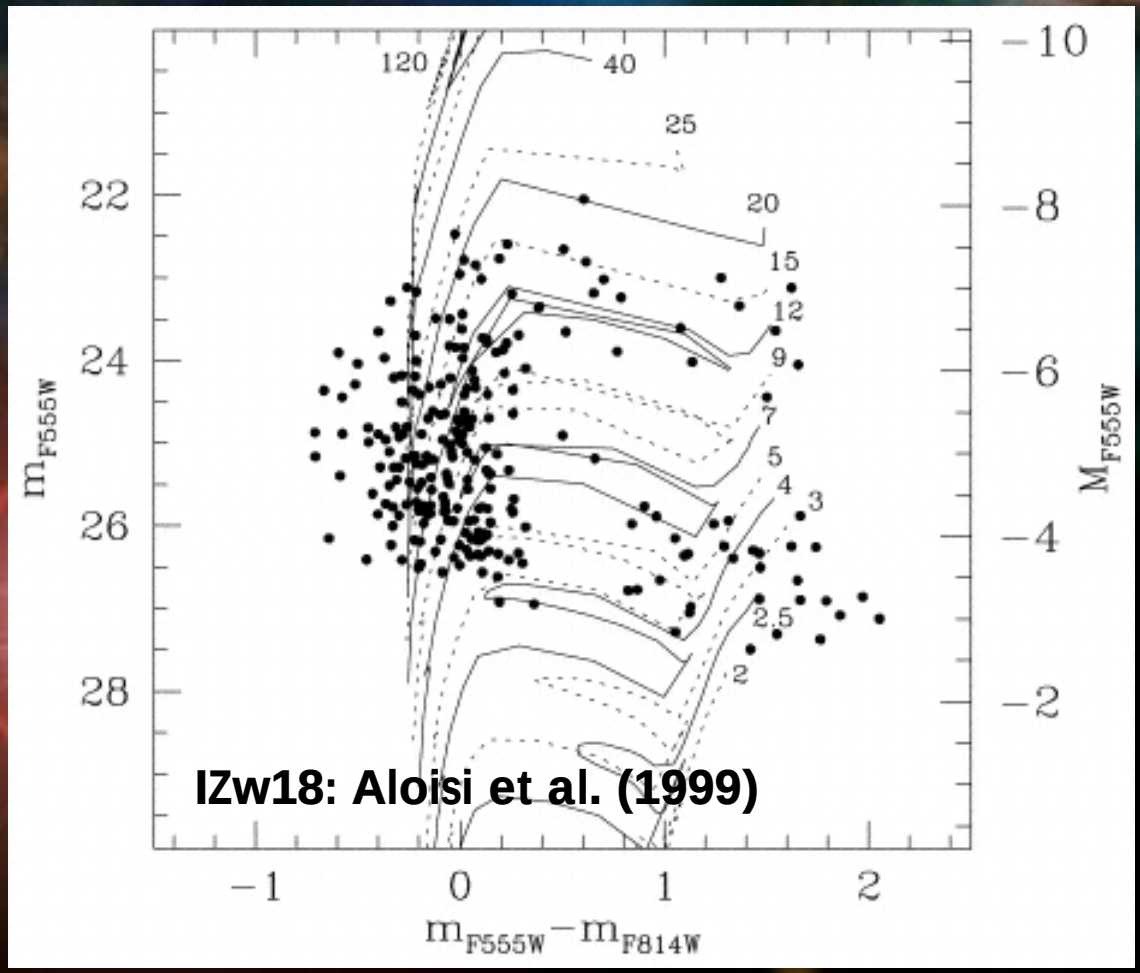


Telles et al. (1997)


Thuan (1985)
IZW18
MK59
MK36
MK209
MK49
Im
M15
M92
M13
M3
4772-10
M87-8
M69
Scd, Sd
Sc
Sbc
Sb
SO/a, Sa, Sb
E
+ Blue Compact Dwarf Galaxies
O Galactic Globular Clusters
• Virgo dE
△ SMC Globular Clusters
▽ LMC Globular Clusters
A_V=0.5
U-V
V-K
0.0
1.0
2.0
3.0
4.0

… make them very suitable in order to answer some open questions about …

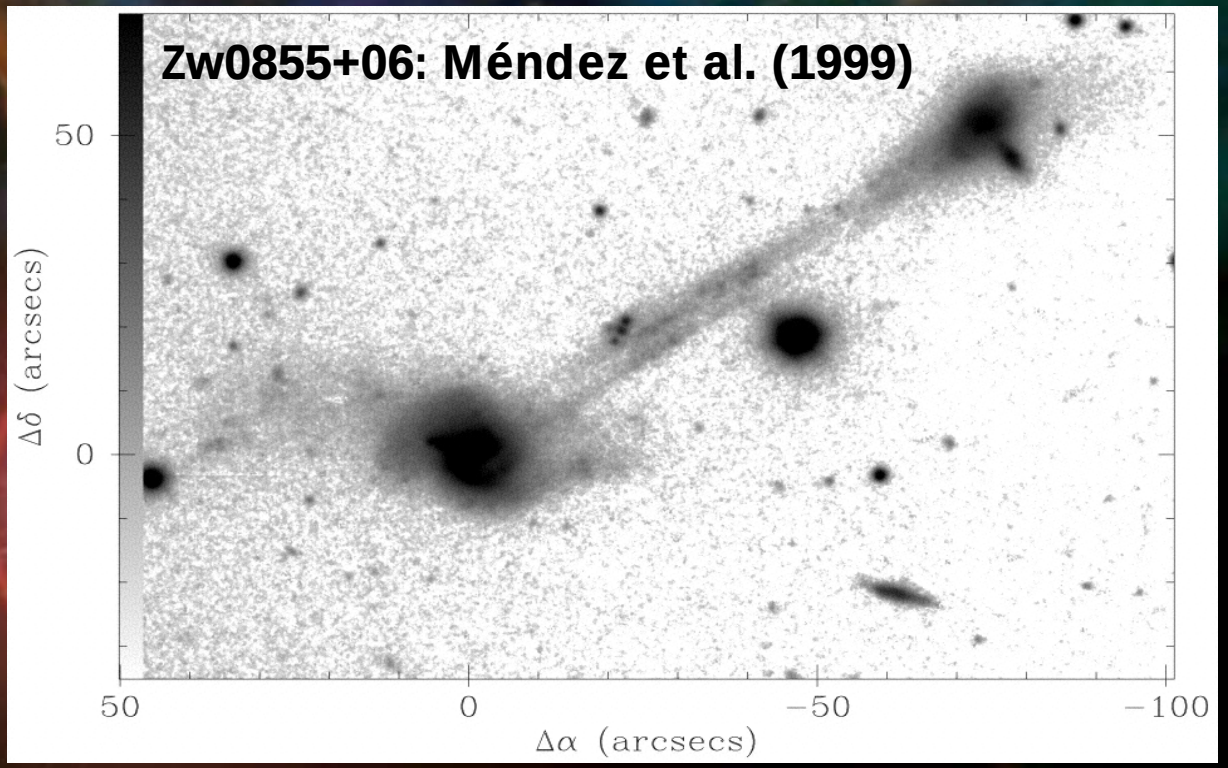
… if they are indeed recently formed objects,



IZw18: Aloisi et al. (1999)

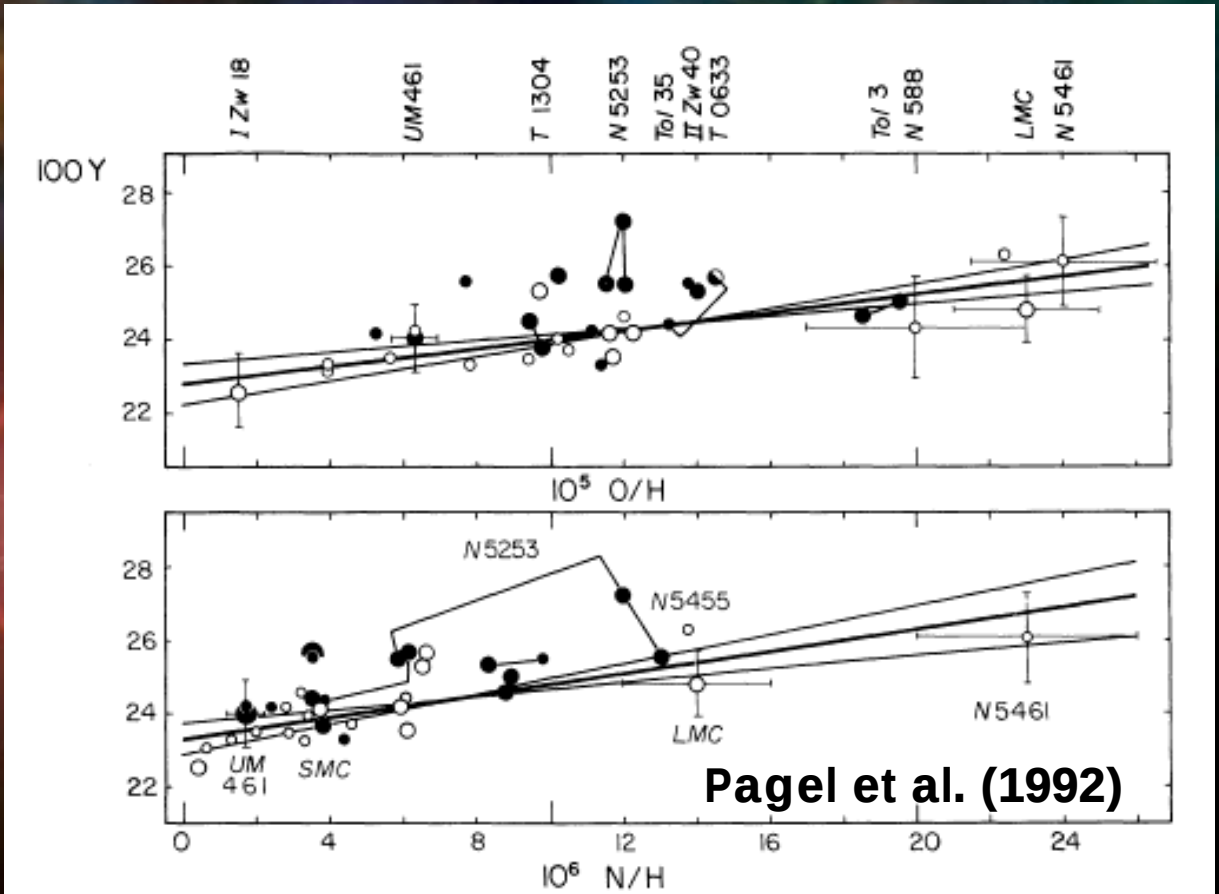
… make them very suitable in order to answer some open questions about …

… the triggering and the nature of the proccesses of star formation,



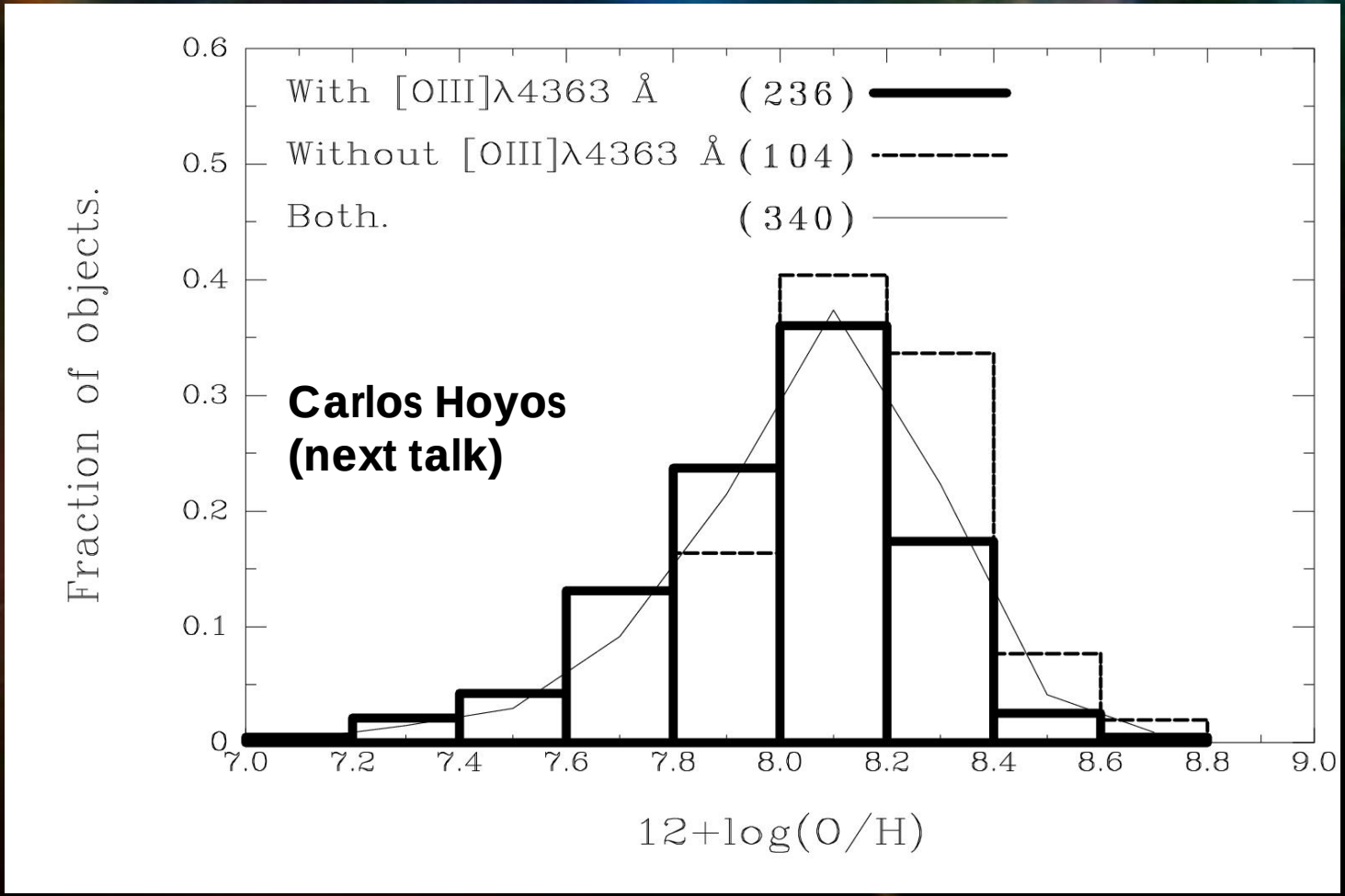
… make them very suitable in order to answer some open questions about …

… their chemical abundances (primordial hellium, chemical evolution, etc…).



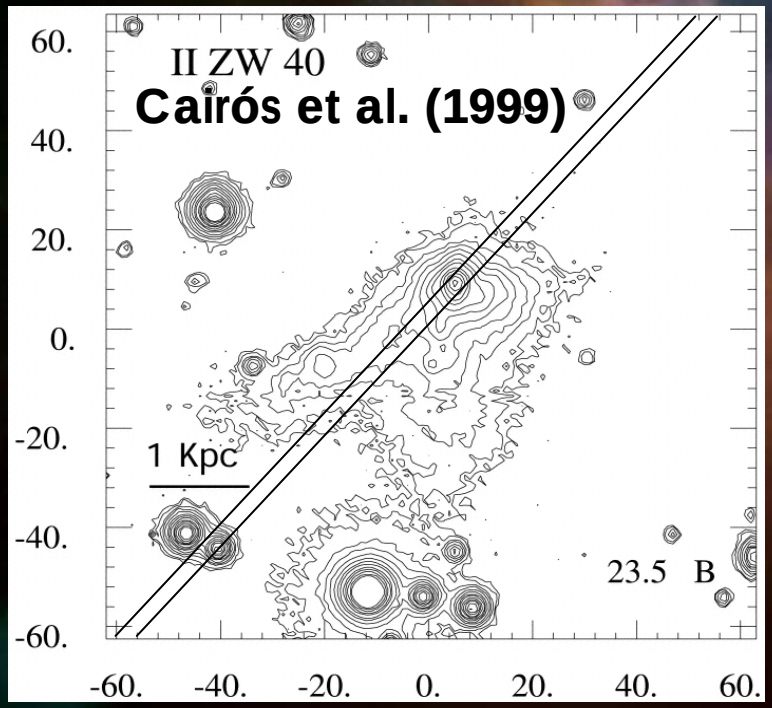
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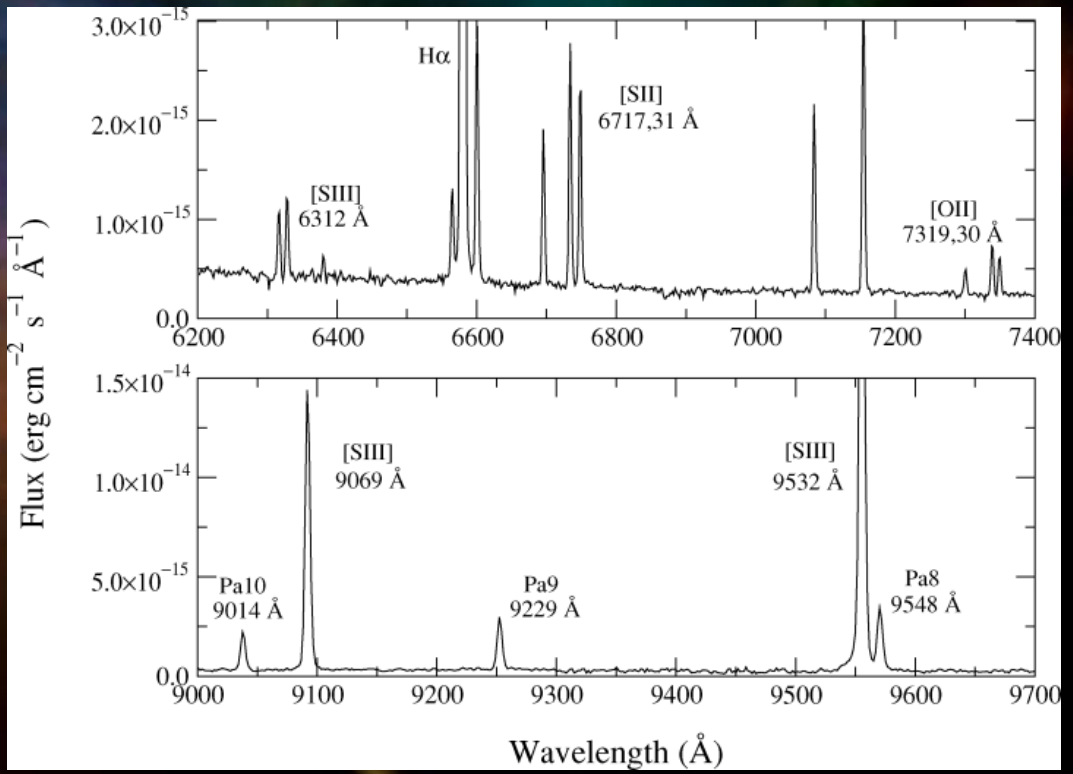
… the actual metallicity distribution of HII galaxies.



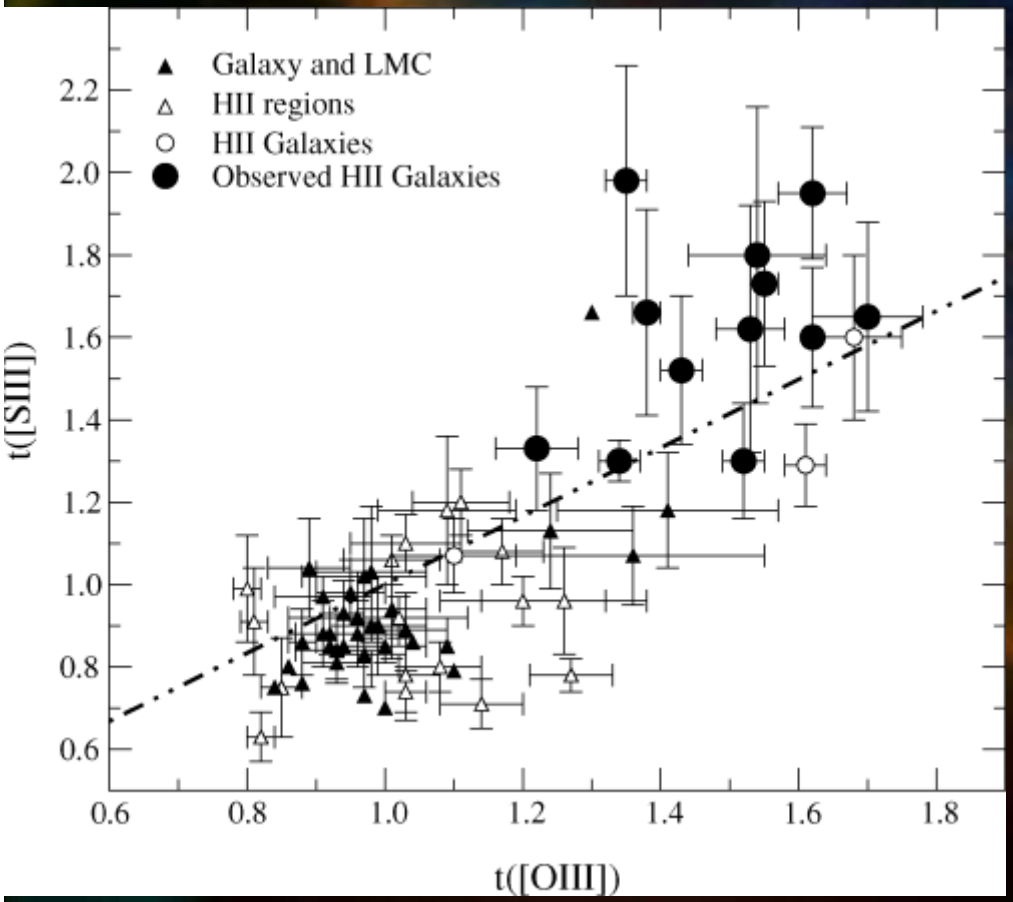
In our previous work (PhD. Thesis E. Pérez-Montero, Pérez-Montero & Díaz, 2003) we studied a sample of 12 HII galaxies through...

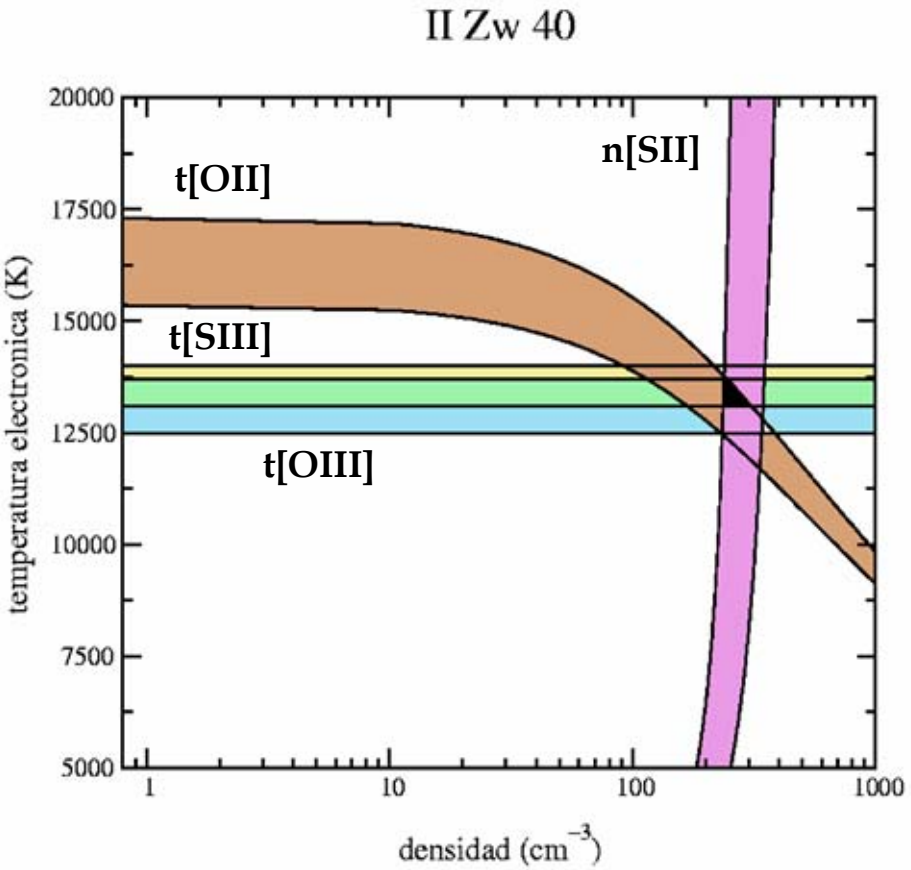
... spectrometric observations in the 7000Å -1μ range (IDS-INT) ...

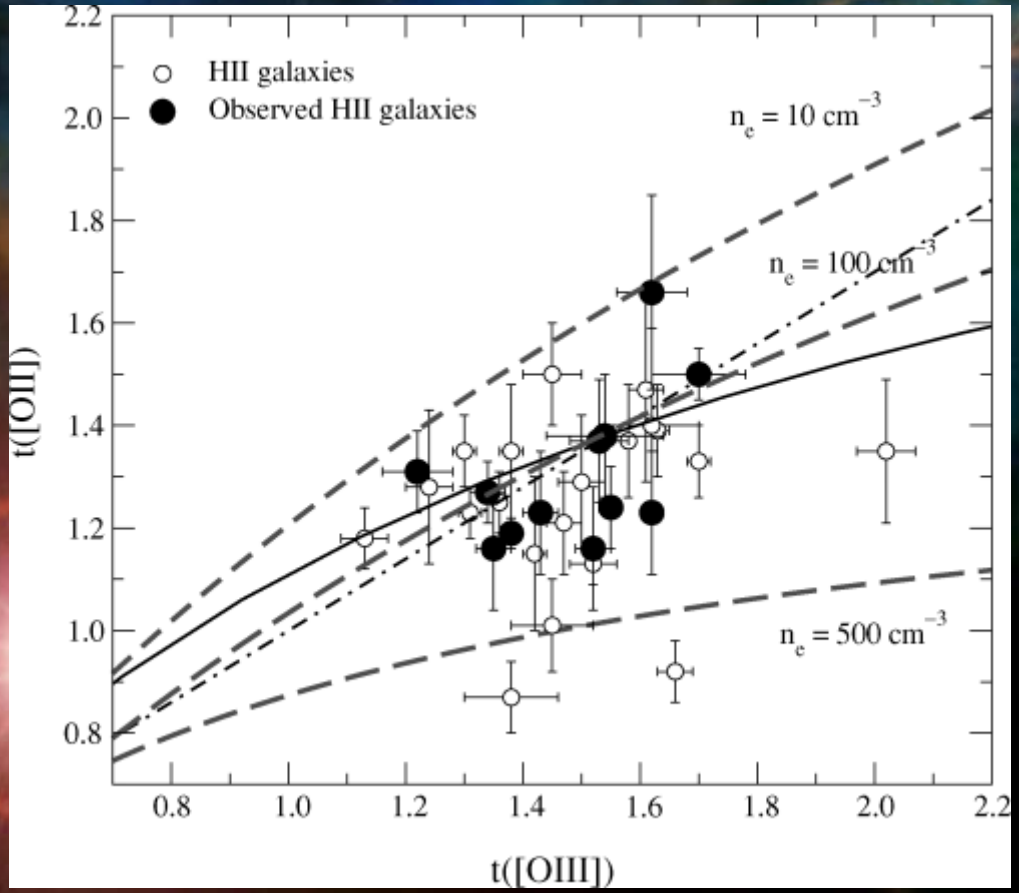




This range, added to the optical one, allows to measure more than one electron temperature and to study the inner ionization structure of the nebula.



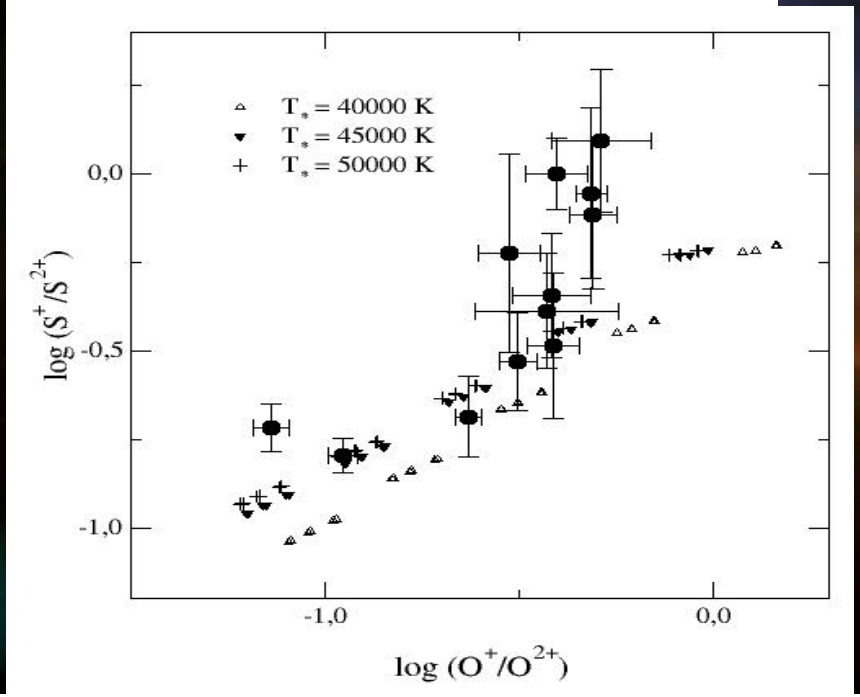


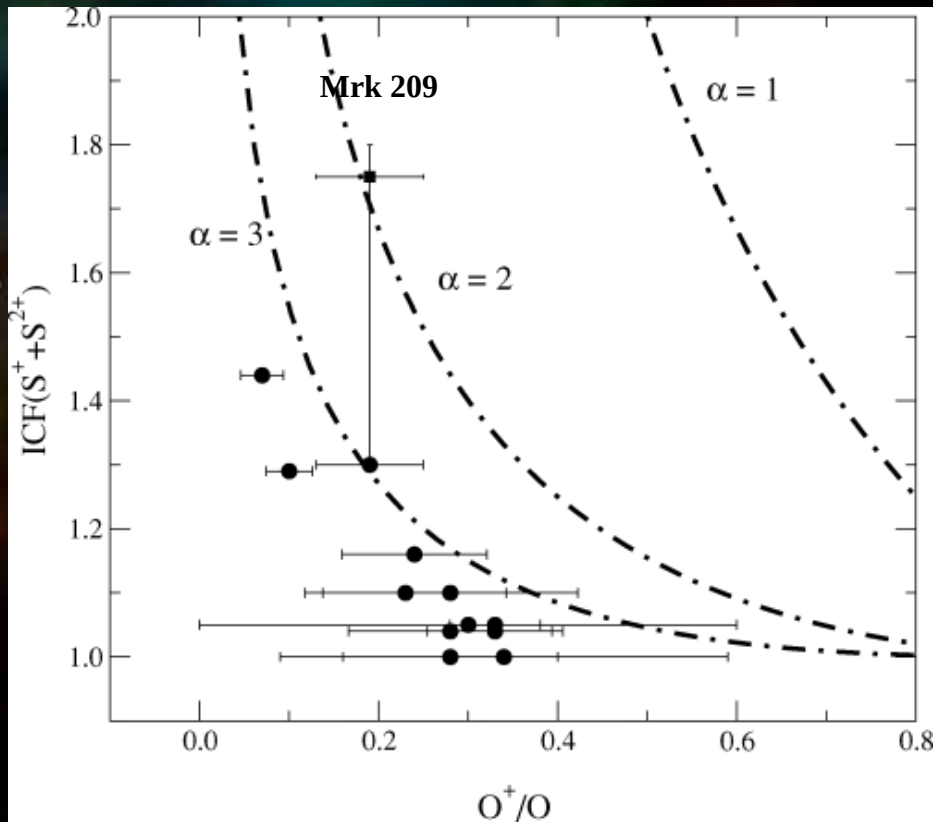

HII galaxies
Observed HII galaxies
n_e = 10 cm^{-3}
n_e = 100 cm^{-3}
n_e = 500 cm^{-3}
t([OII])
t([OIII])
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2

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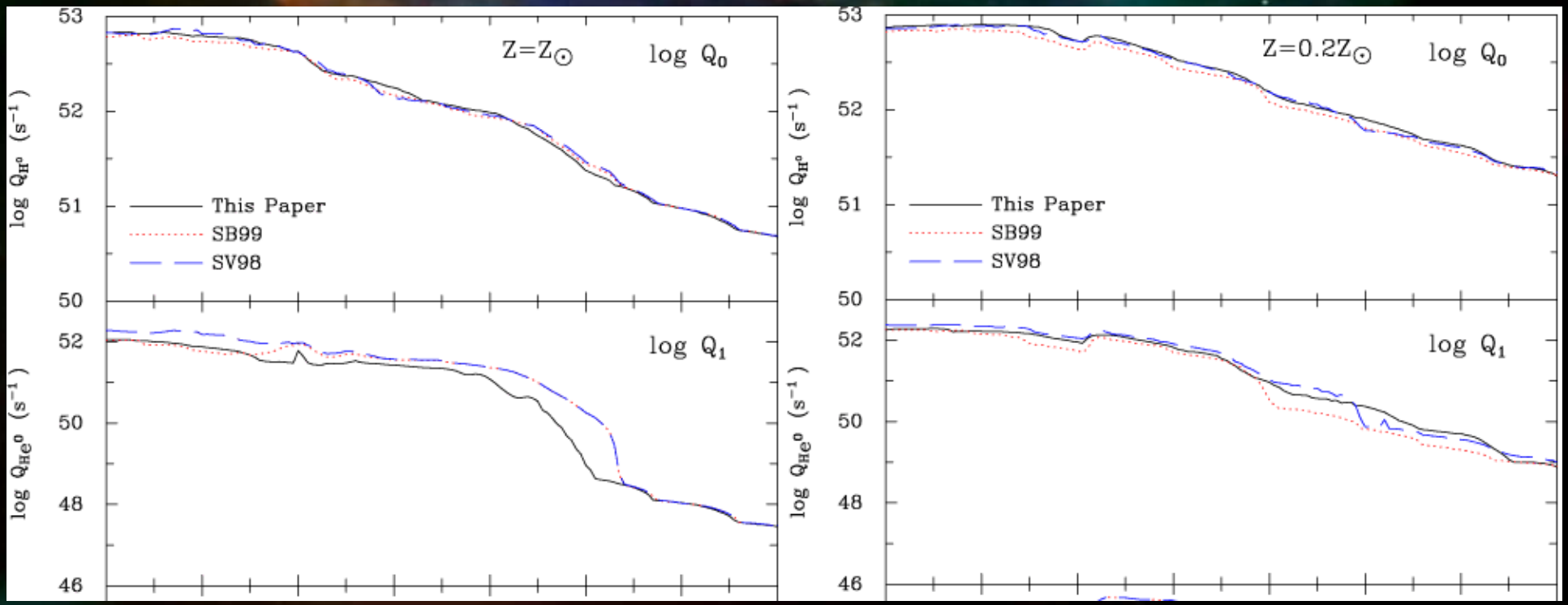
... single star (CoStar model atmospheres) photoionization models with updated atomic coefficients...

$$ICF(S^+ + S^{2+}) = \left[1 - \left(1 - \frac{N(O^+)}{N(O)}\right)^{\alpha}\right]^{-1/\alpha}$$

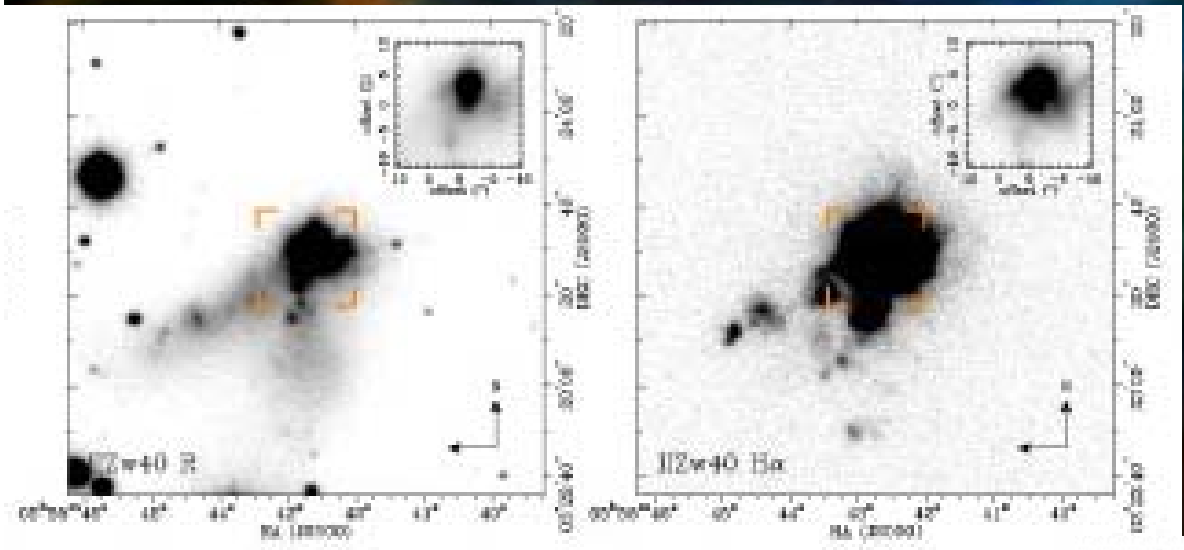


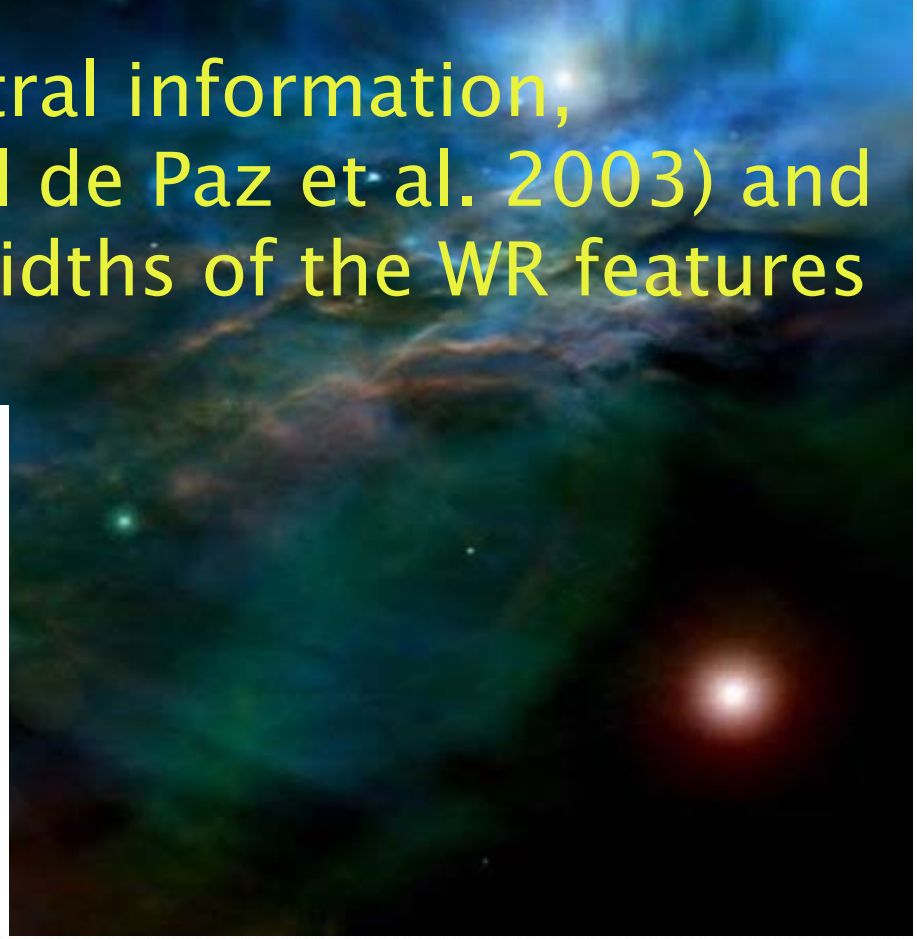


In this work we model the same objects with the new model atmospheres: O,B stars: WM-basic (Pauldrach et al. (2001), WR stars: Hillier & Miller (1998) as implemented in StarBurst99 (Smith et al. 2002)

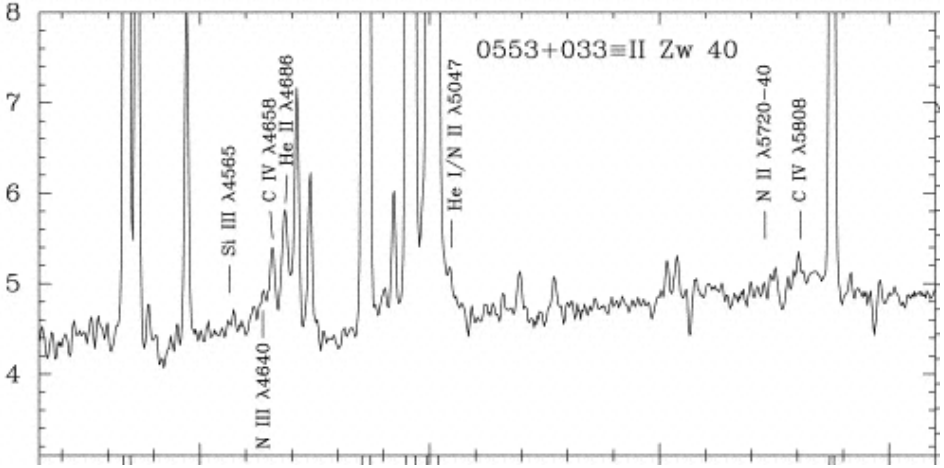


Moreover, we add to the spectral information, photometry in B, R and Hα (Gil de Paz et al. 2003) and the intensity and equivalent widths of the WR features (Guseva et al. 2000).

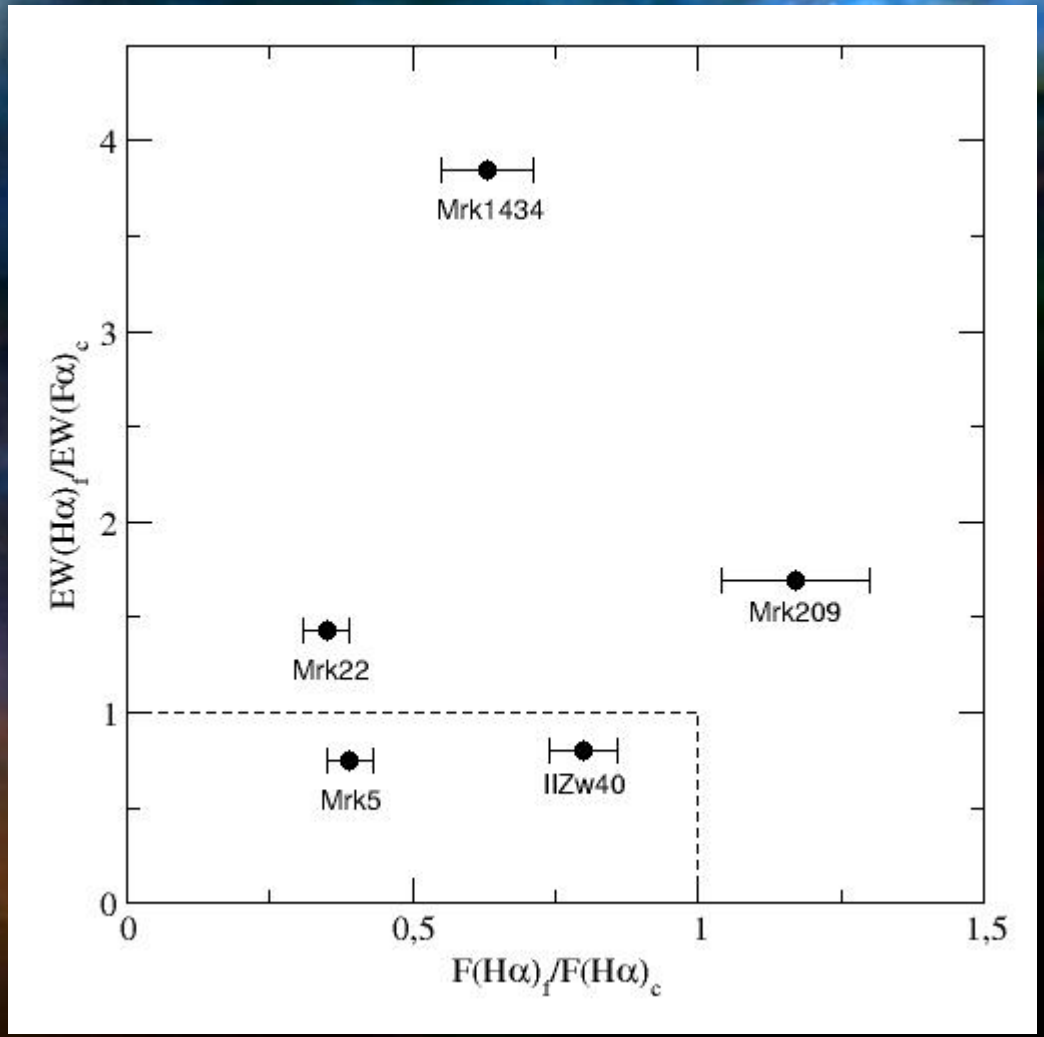








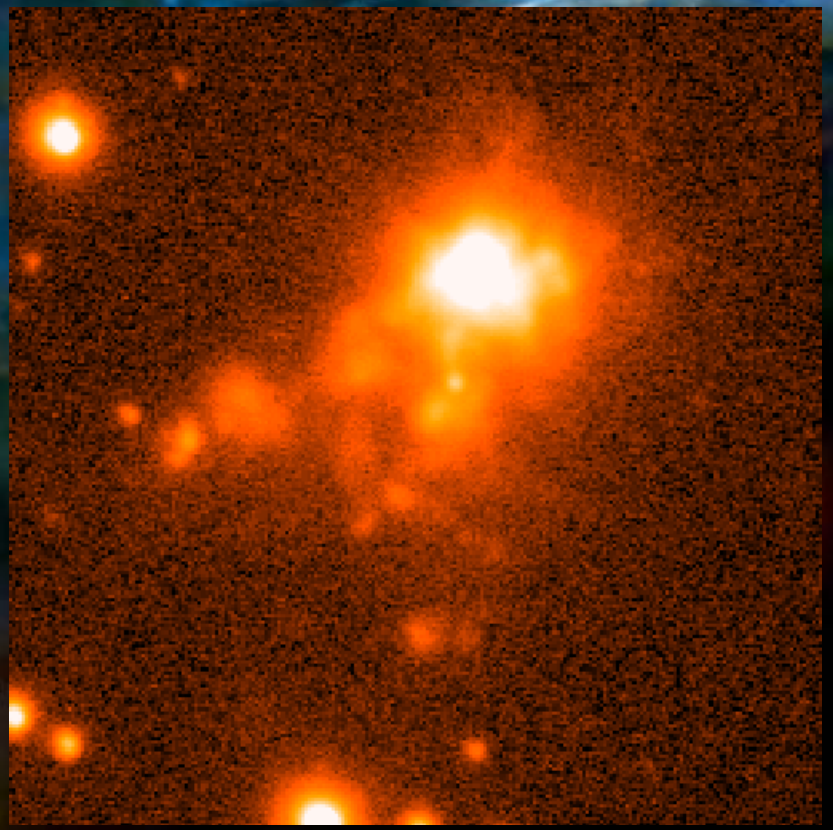
The complete information is avalaible for 5 of the 12 objects, but … IIZw40 is the object where there is a better agreement between all the observational data.



Some properties of IIZw40

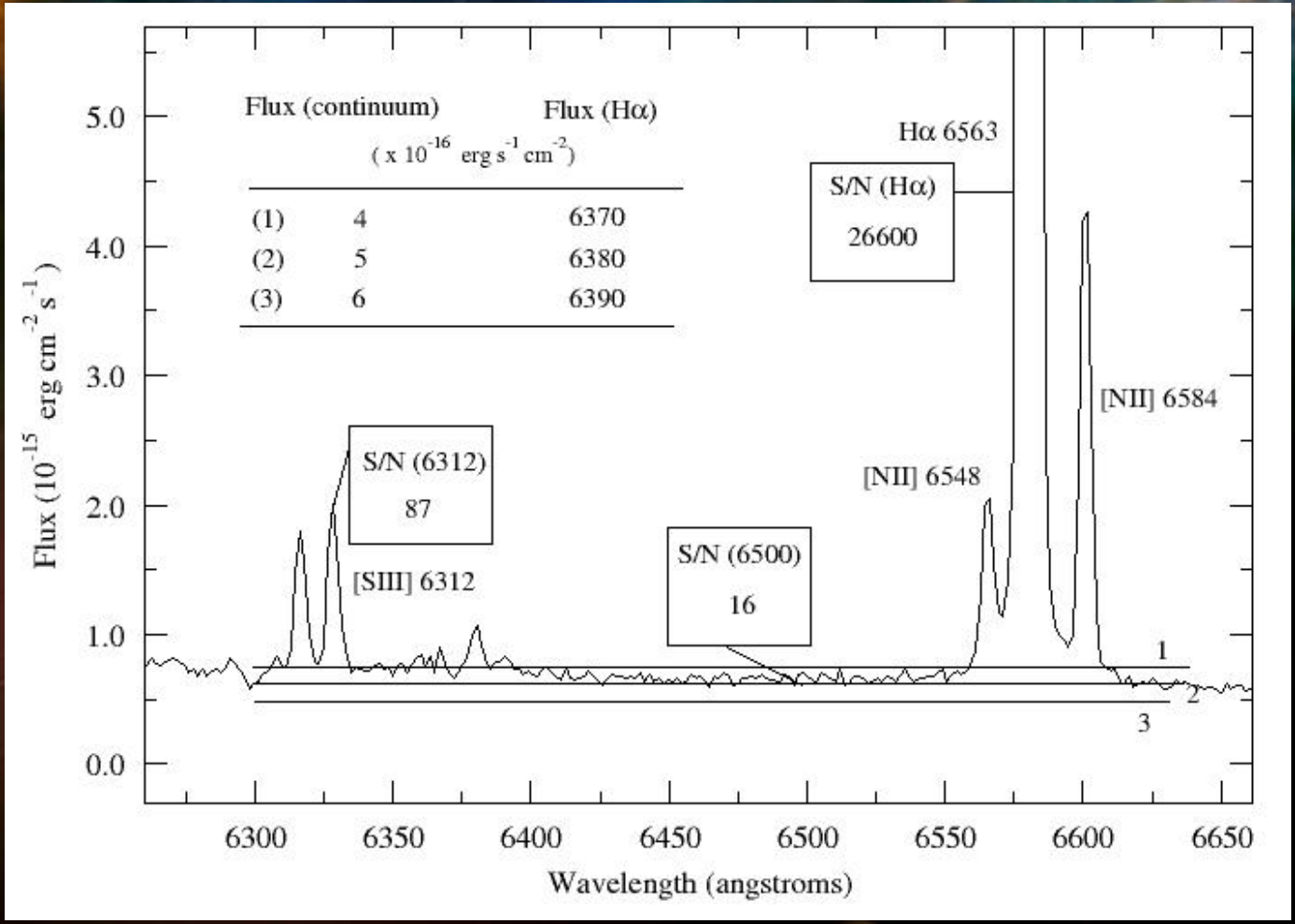
IIZw40	
B (mag)	11.87±0.04
EW(Hβ) (Å)	272
D (Mpc)	10.1±0.3
d (pc)	$\approx$ 250
log Q(H) (phot $\cdot$ s^{-1})	53.267
α_c (M$_\odot$/year)	1.34±0.21
n$_e$ (cm^{-3})	290±40
log U	-2.23±0.08
log M(HI) (M$_\odot$)	8.64[a]
log M(HII) (M$_\odot$)	6.09
log M$_*$ (M$_\odot$)	6.40

[a]Brinks & Klein, 1998



It's a iI,M BCD. The emission in R has a 40% of its origin in Hα. Likely, it's a merging object.

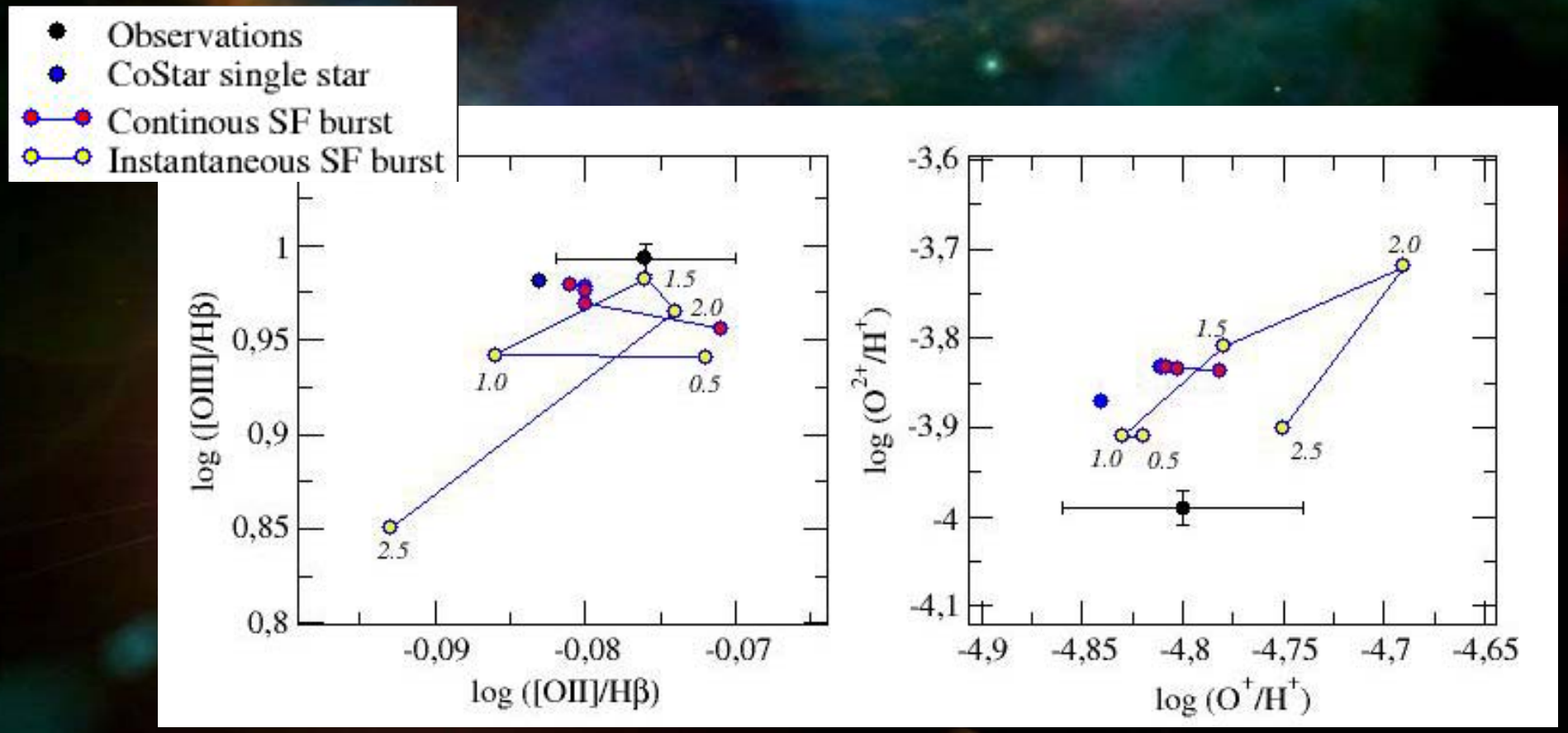
Moreover, its high signal to noise ratio even for the weakest emission lines gives much confidence in the measurement of the intensities



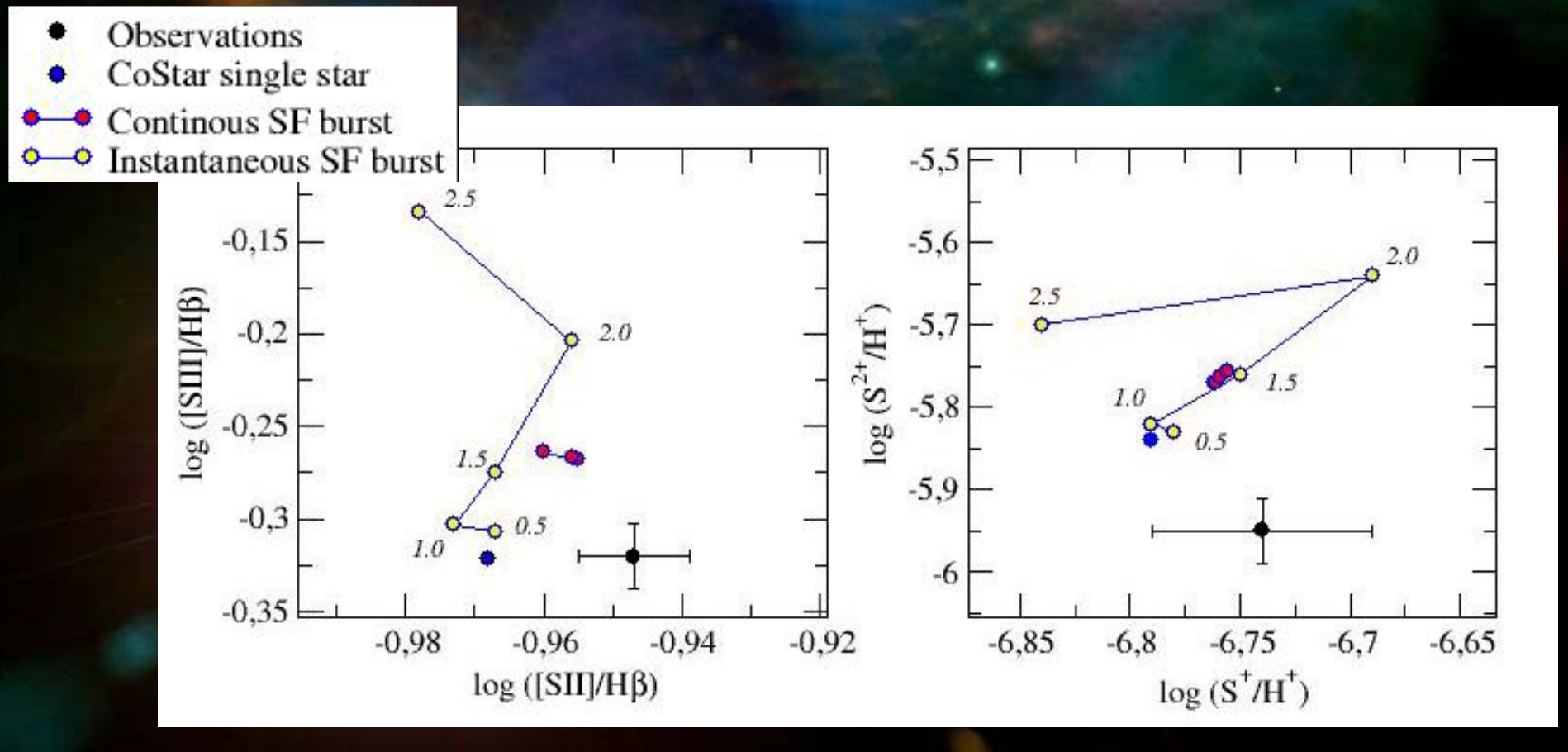
We have used again the Cloudy photoionization code, but with the new atmospheres as implemented in Starburst99 in order to study the stellar populations and check differences in the derived abundances.

Model properties	
Code	Cloudy 96.05 (Ferland, 2003)
Cluster atmospheres	Starburst99
O-B atmospheres	WM-basic, Pauldrach et al.(2001)
WR atmospheres	Hillier & Miller (1998)
Star formation	Instantaneous burst
IMF	Salpeter (x=2.35)
IMF limits	0.8 - 120 $M_\odot$
Mass limit (SN)	8 $M_\odot$
Mass limit (BH)	120 $M_\odot$
Metallicity	0.004 ($\approx$ 1/5 $Z_\odot$)
Loss mass	Standard
Wind model	Theoretical
Density	Constant
Abundances	O,S,N and rest scaled to solar (Allende-Prieto et al., 2001)
Dust	only depletion

To find out the age of the population controlling the photoionization equilibrium of the gas, we do some trials with the observed properties (density, metallicity, Q(H), radius).



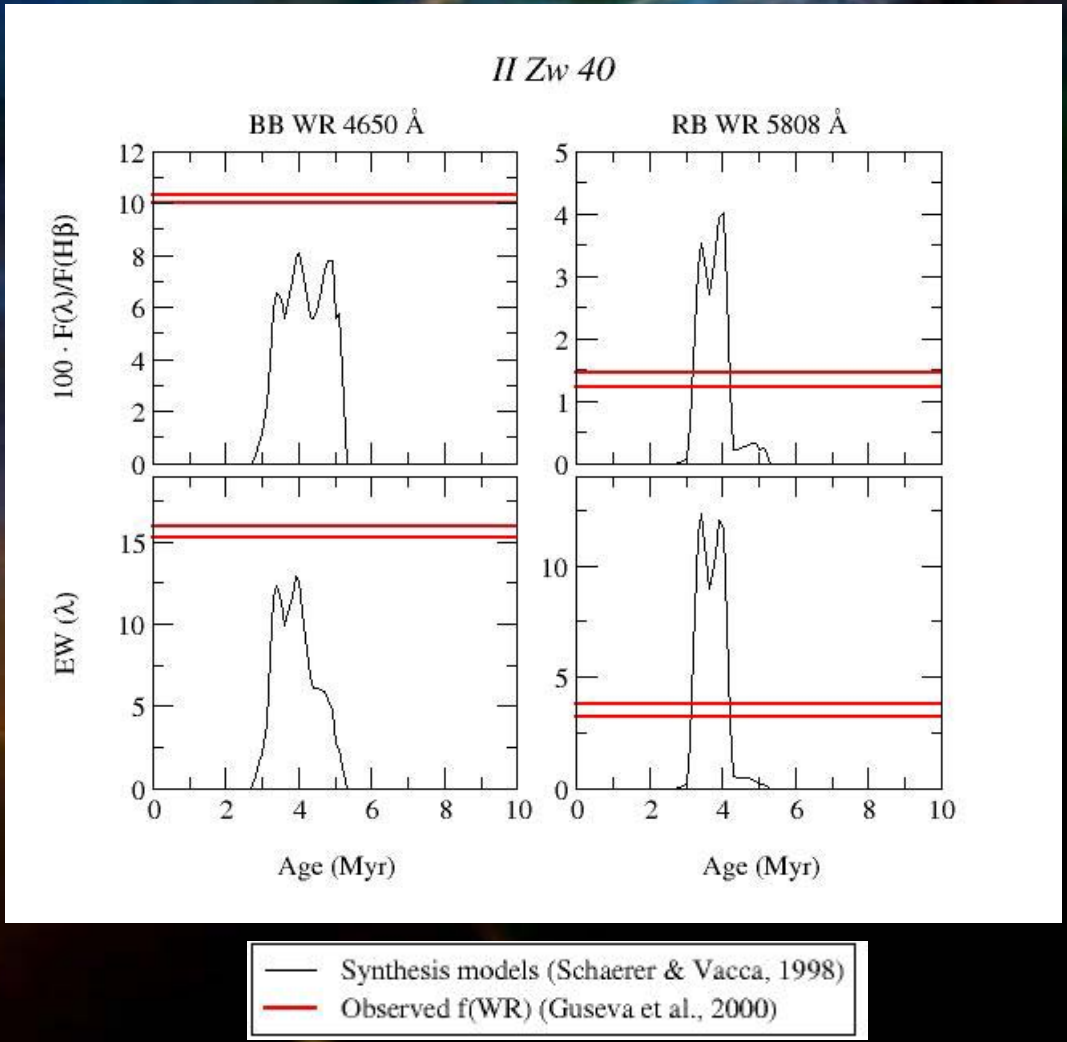
To find out the age of the population controlling the photoionization equilibrium of the gas, we do some trials with the observed properties (density, metallicity, Q(H), radius).



II Zw 40	Observed	Single burst model (1.5 Myr)
EW(Hβ) (Å)	272 ± 2	378

Instantaneous burst
1 Myr burst
2 Myr burst
4 Myr burst

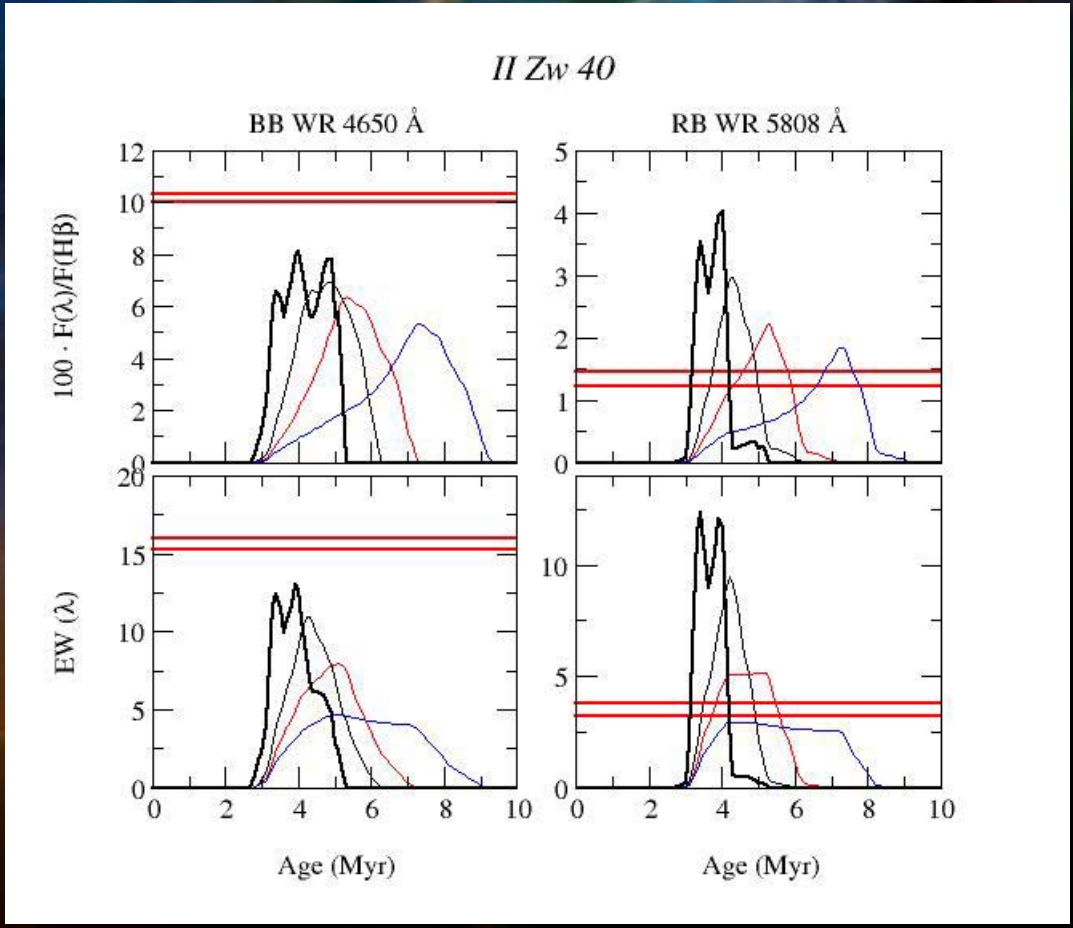
Nevertheless, as the observed EW(Hβ) are lower than predicted by an unique burst with less than 2 Myr and we observe WR features we try to composite the main population with other older.



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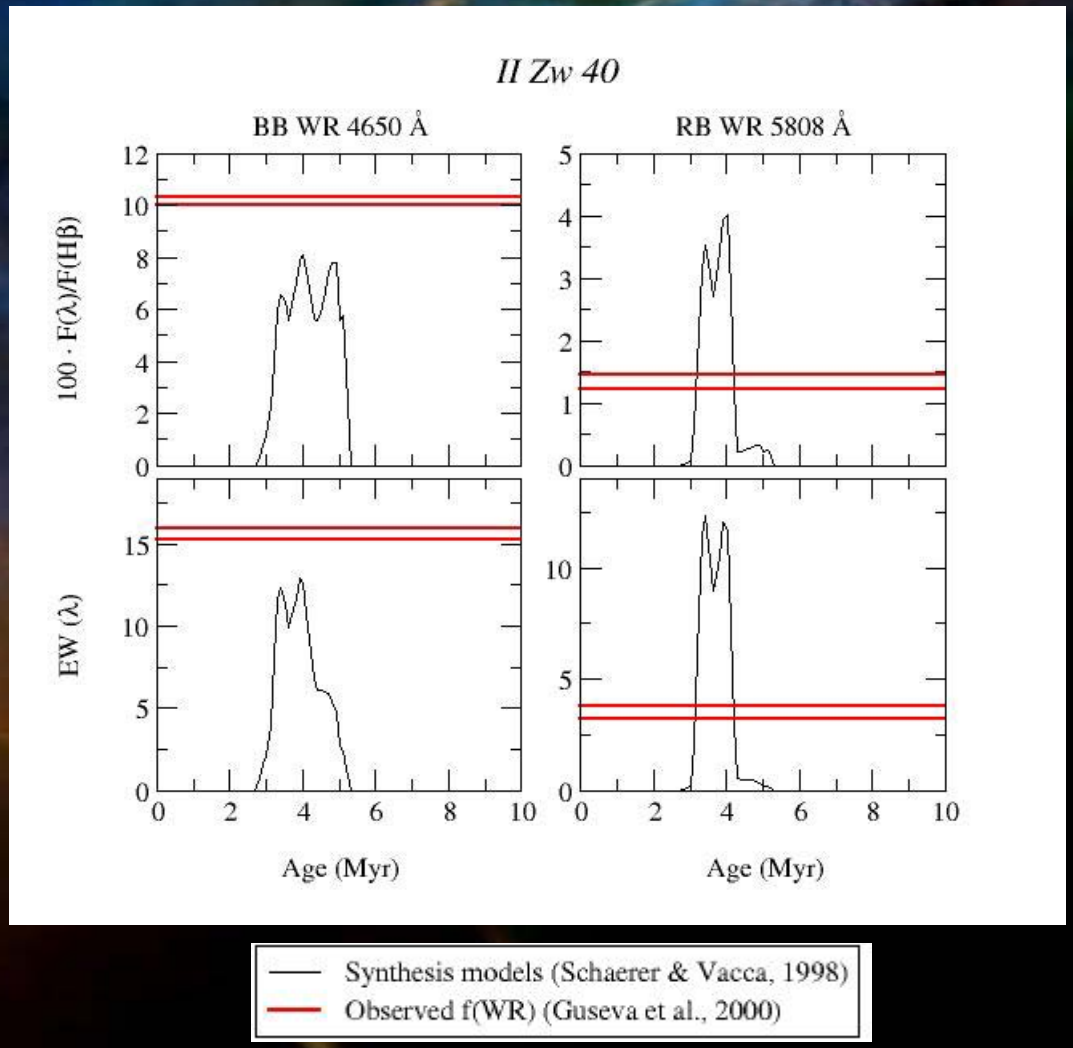
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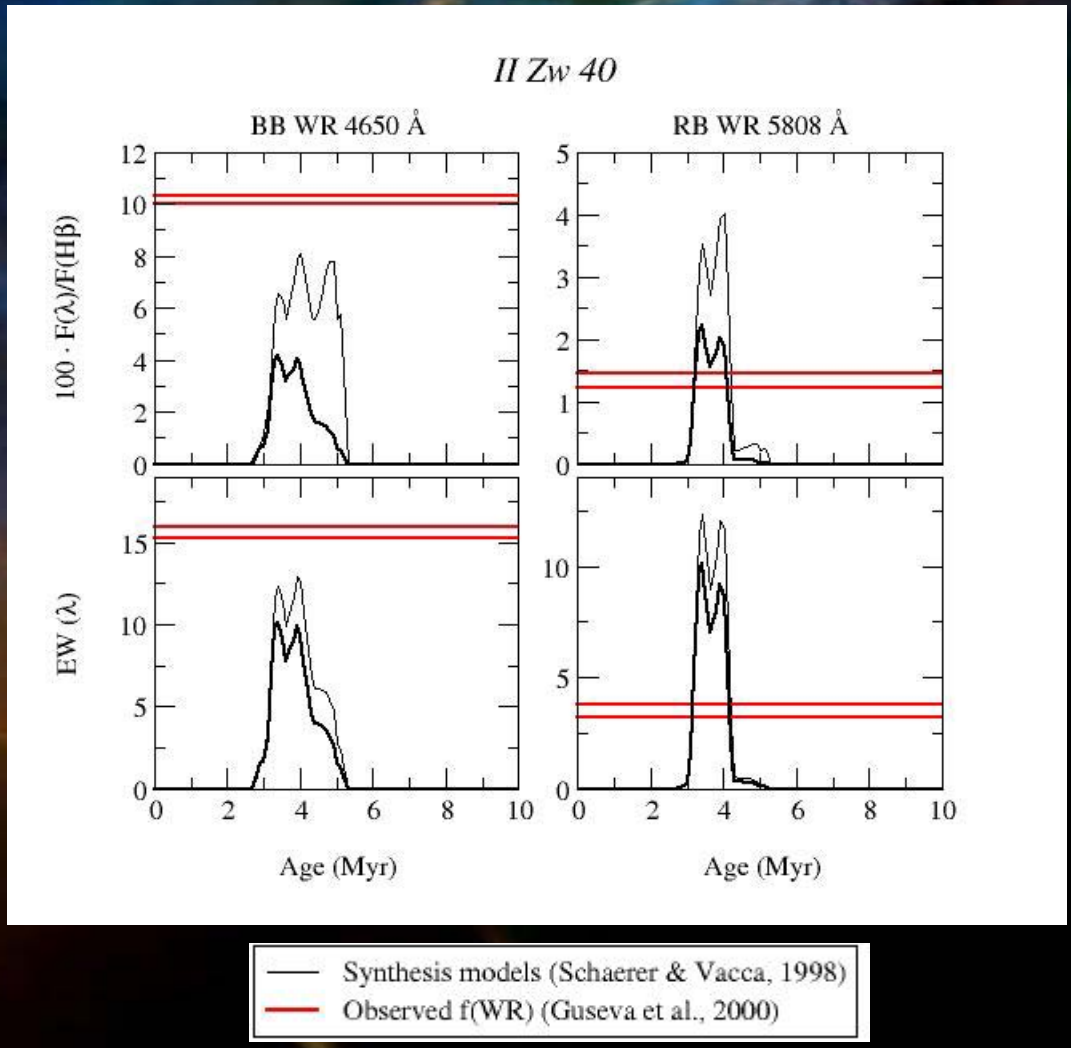
II Zw 40	Observed	Single burst model (1.5 Myr)	Composite models (1.5 + 3.2 Myr)	(1.5 + 4.2 Myr)
EW(Hβ) (Å)	272 ± 2	378	267	269

In order to assign an age to the older burst we must compare the observed WR features with those predicted by the models, once we've taken into account the younger cluster.

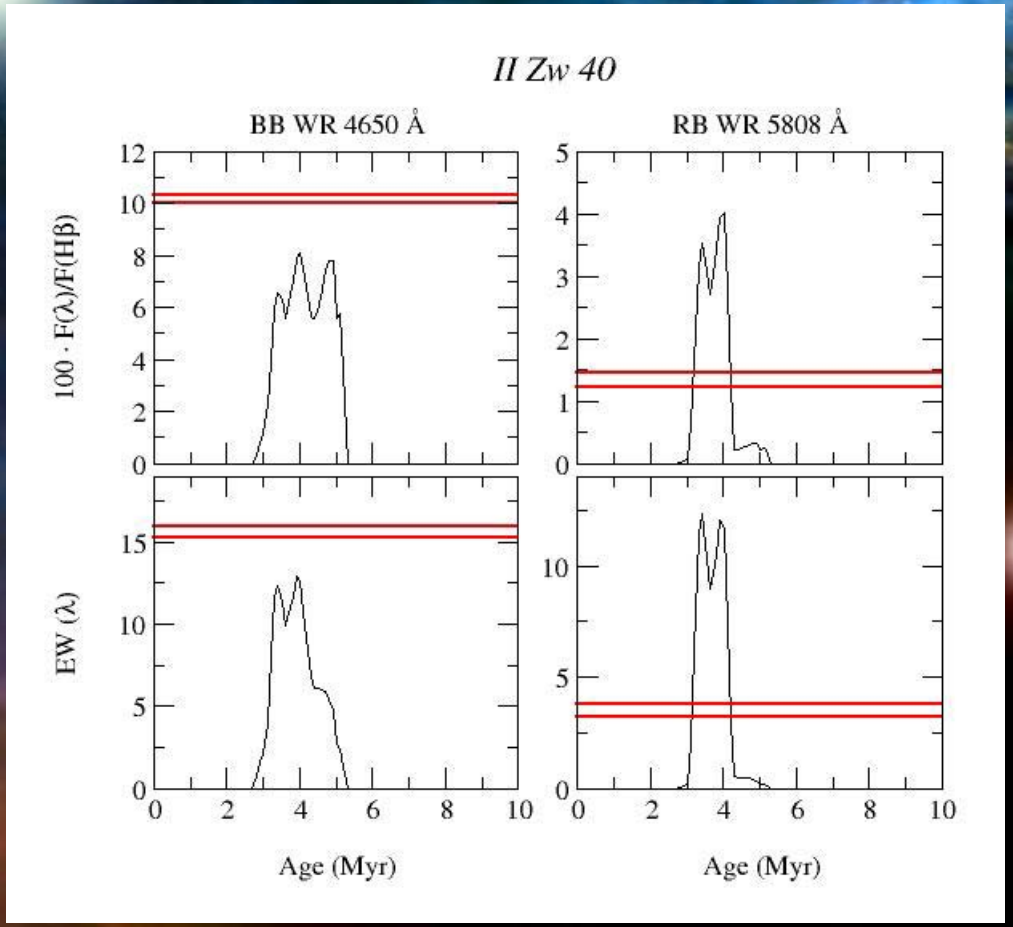


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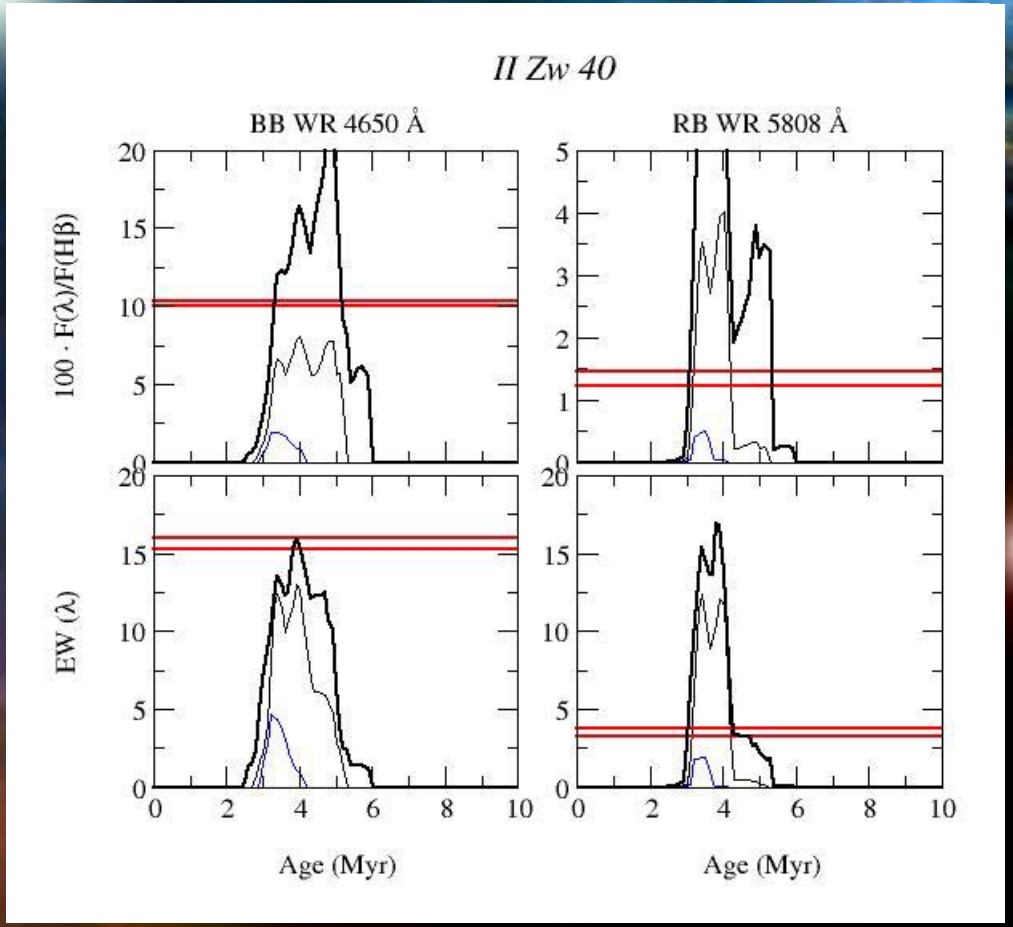
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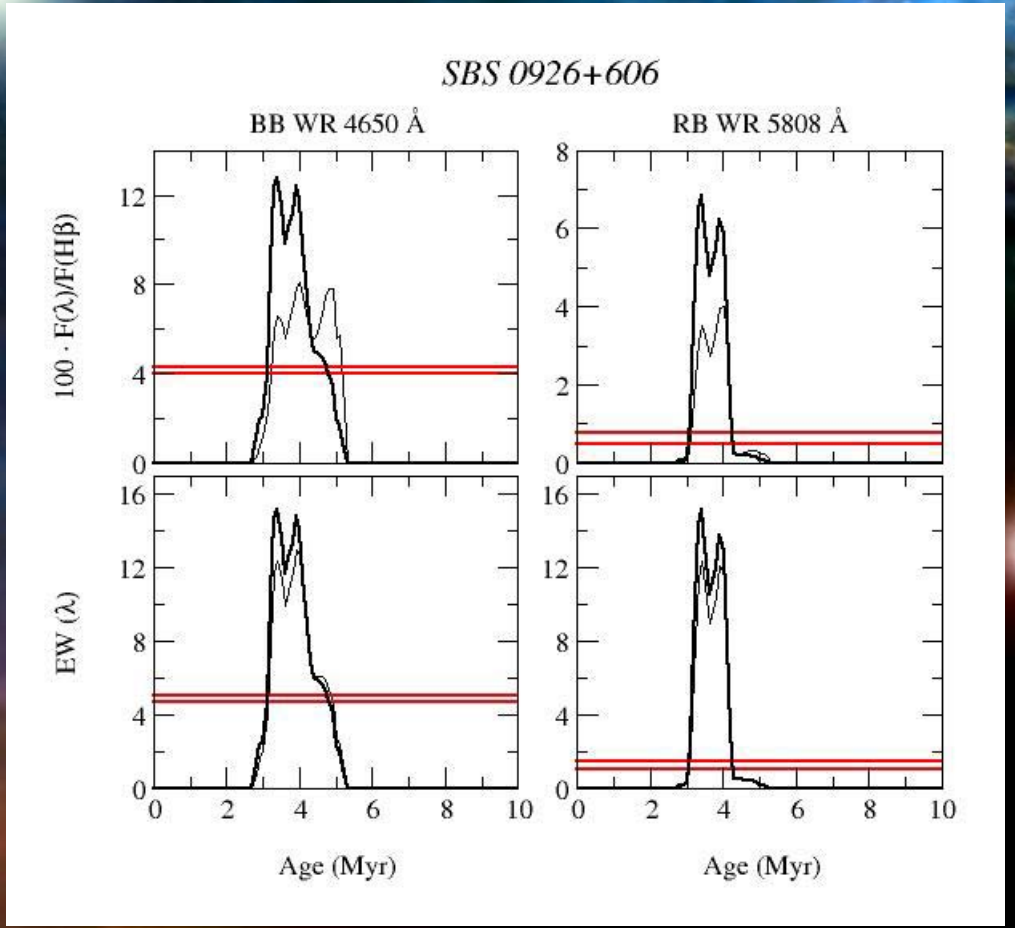
We've assessed the possibility of an enriched younger cluster as proposed with the gas by Stasińska & Izotov (2002), or an understimated chemical abundance (e.g. temperature fluctuations)



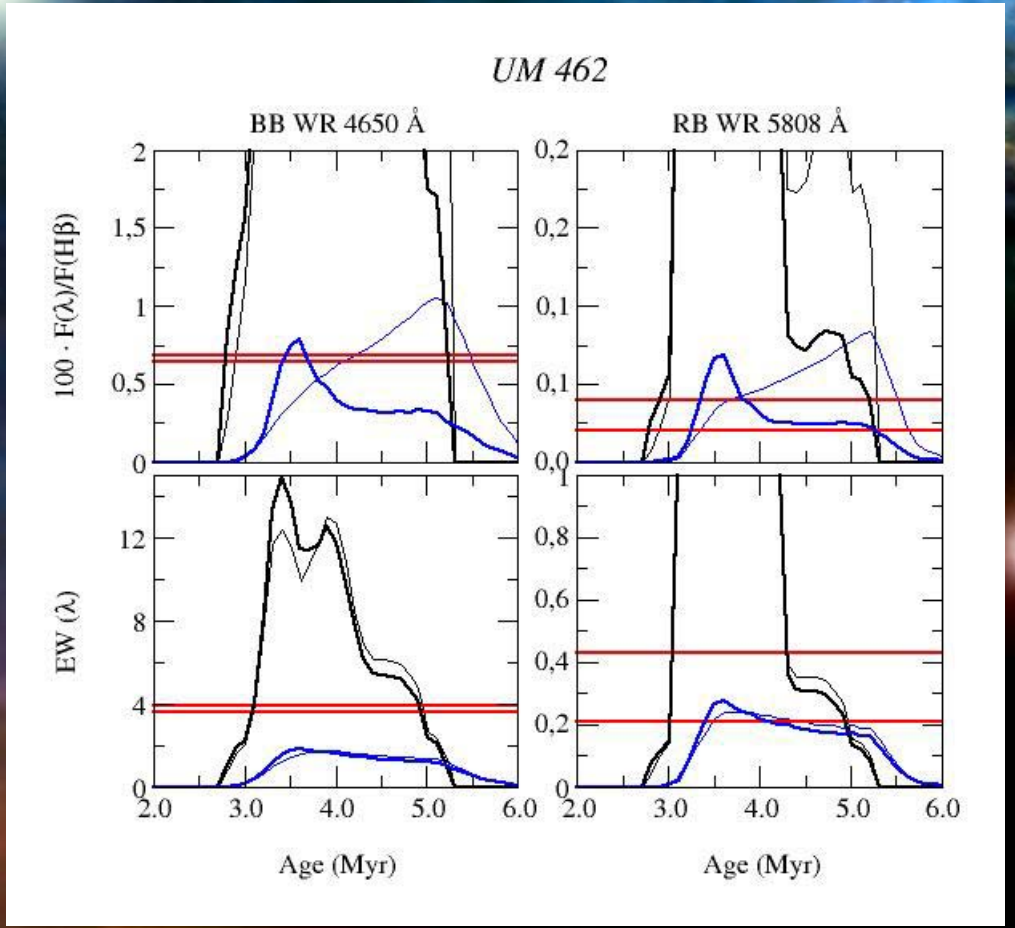
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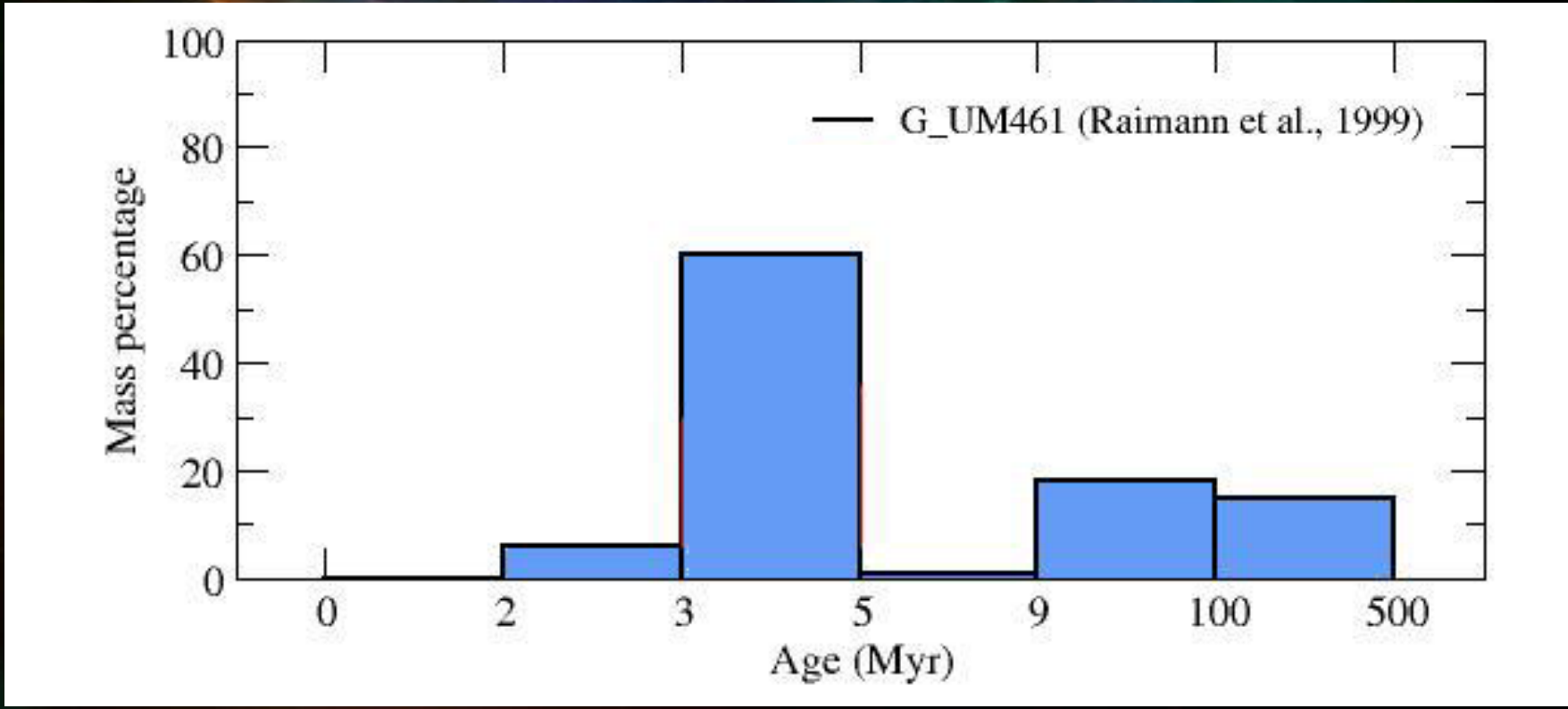


Object	Age y.c. (Myr)	Mass y.c. ($\cdot 10^6$ $M_\odot$)	Age o.c. (Myr)	Mass o.c. ($\cdot 10^6$ $M_\odot$)
II Zw 40	1.5	1.55	3.2	1.05
	1.5	1.88	4.1	1.04
Mrk 5	0.5	0.11	4.0	0.02
SBS 0926+606	0.5	0.80	4.1	1.82
	0.5	1.06	5.0	1.68
Mrk 22	1.5	0.31	4.2	0.57
Mrk 1434	2.0	0.28	4.5	0.96
UM 462	1.5	0.25	4.0[a]	2.46
	1.5	0.86	5.0	2.46
Mrk 209	1.5	0.05	3.2	0.05
	1.5	0.07	4.1	0.04

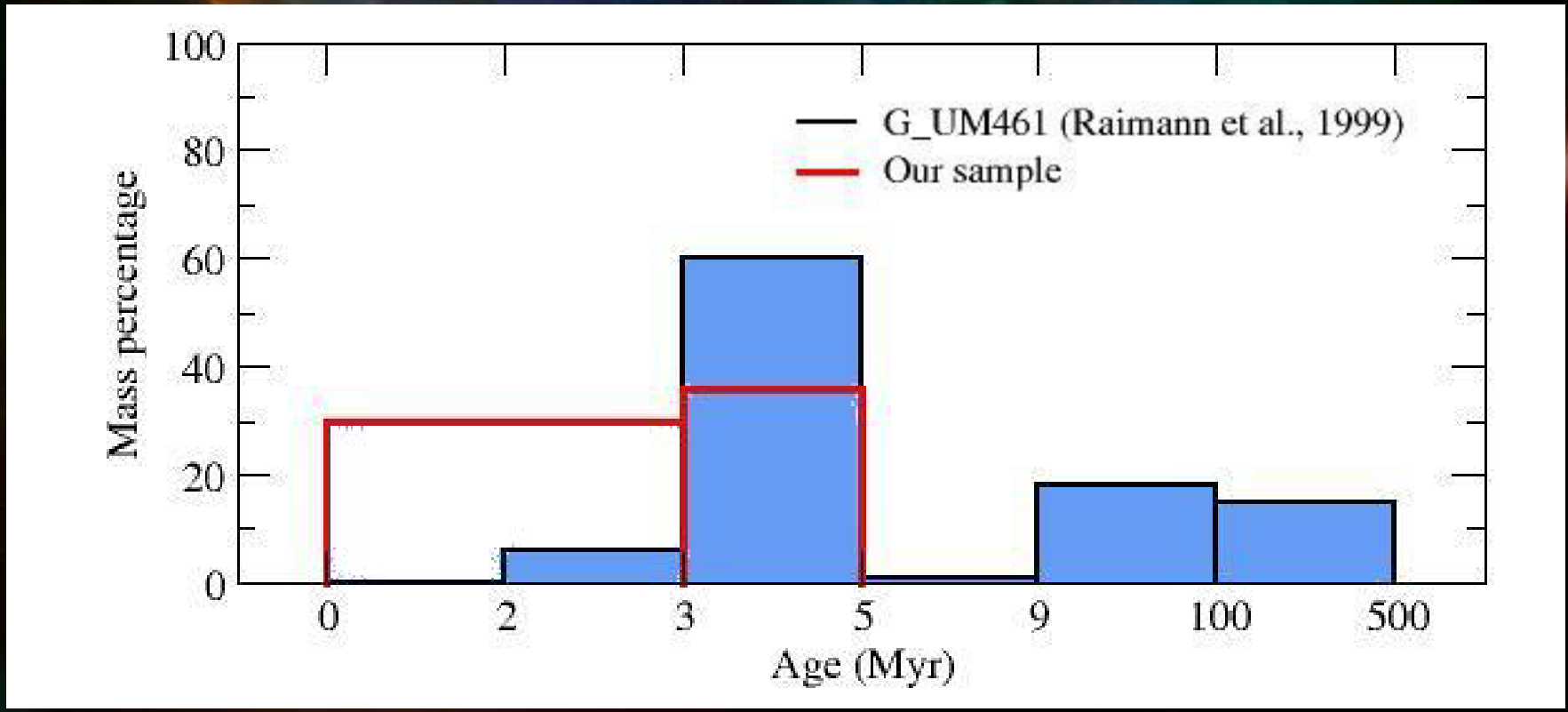
[a] At lower metallicity

For all the 7 objects, we find a composite population of ionizing star clusters as for the sample of GEHRs with WR in Castellanos et al. (2002)

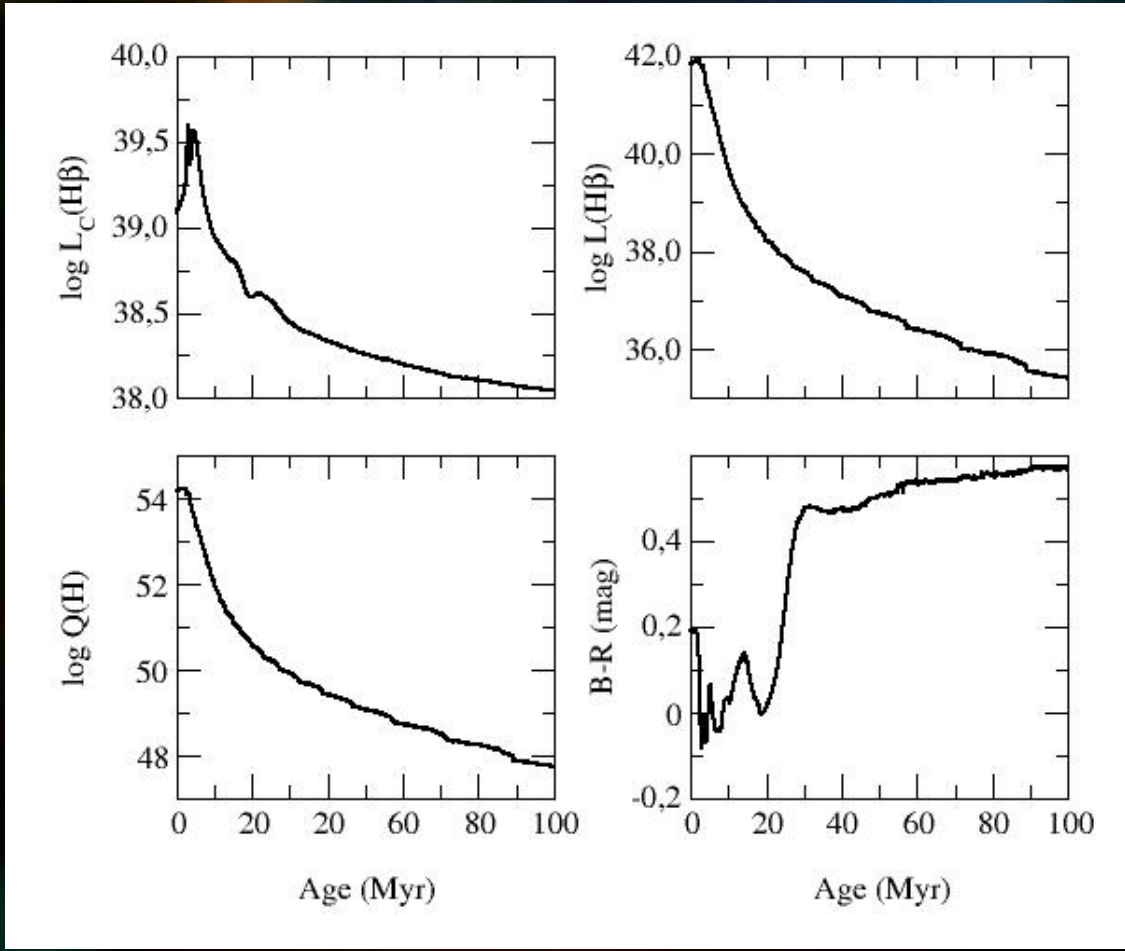
On the contrary as in Raimann et al. (1999), we find that the mass of the younger cluster is almost equal to that in the 3–5 Myr phase.



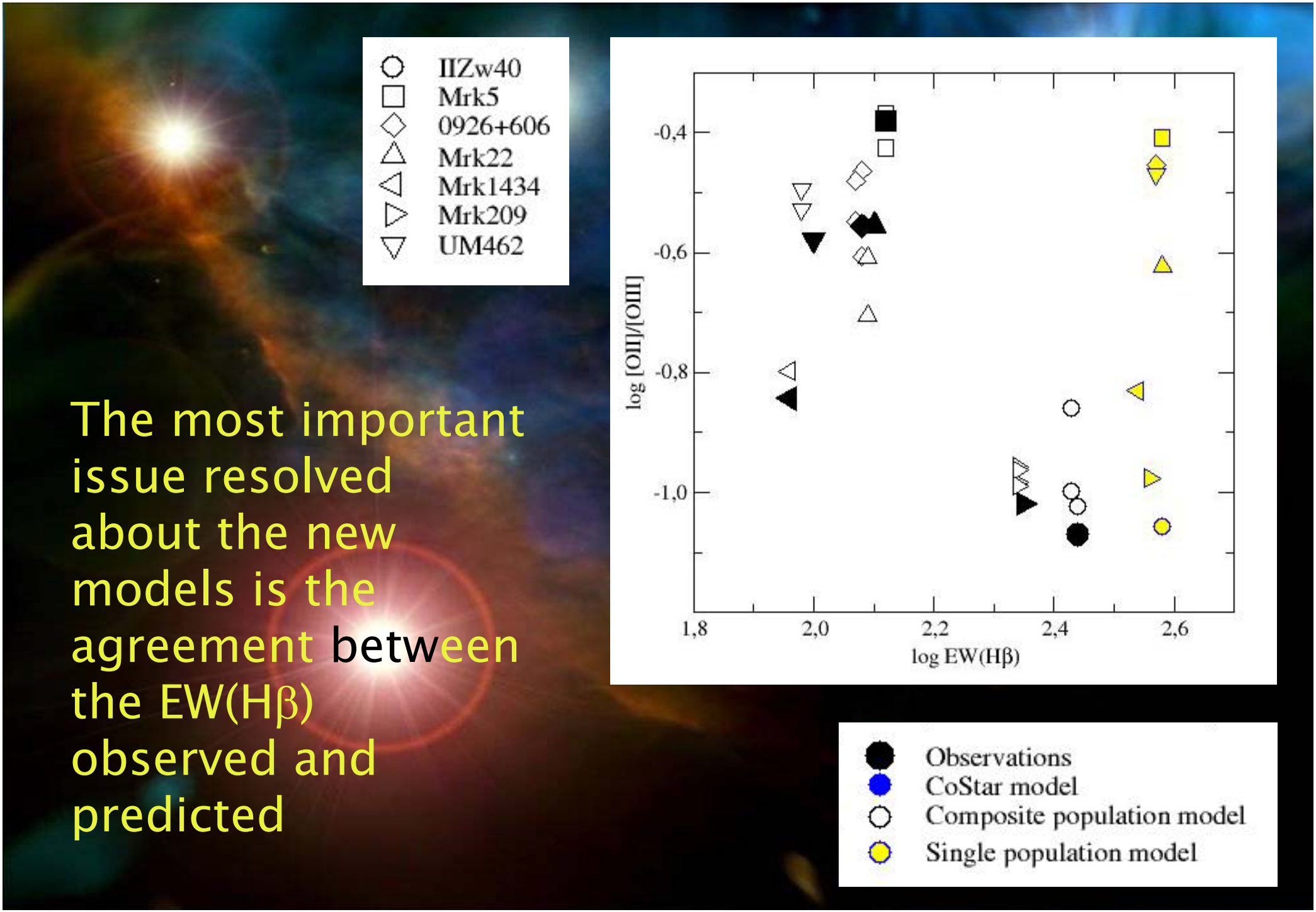
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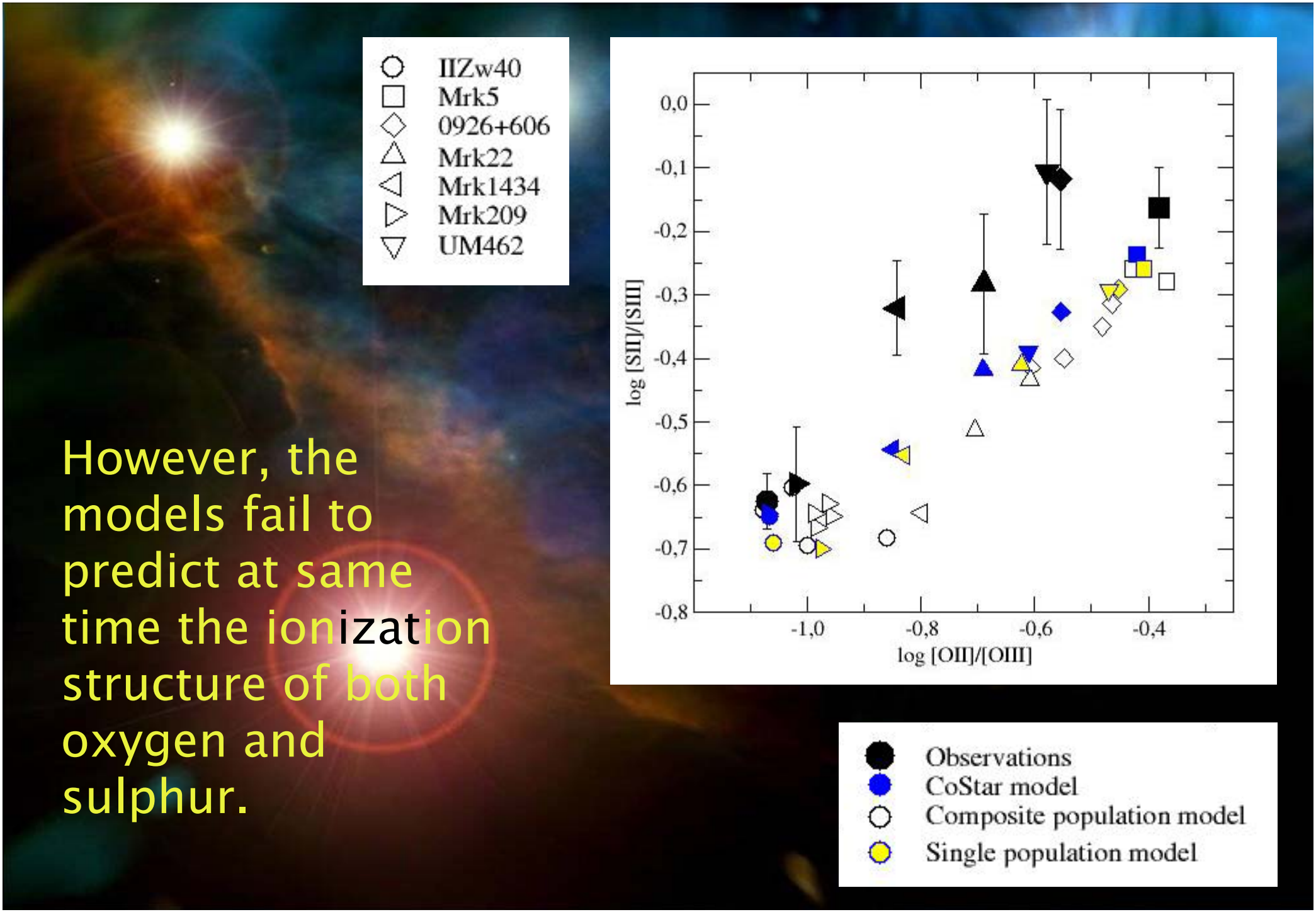
In relation with even older populations in these objects, photoionization models cannot provide any solid conclussion.



For instance, in IIZw40 (B–R = 0.77), there is evidence of a very old population …. combined with a intense reddening effect ?

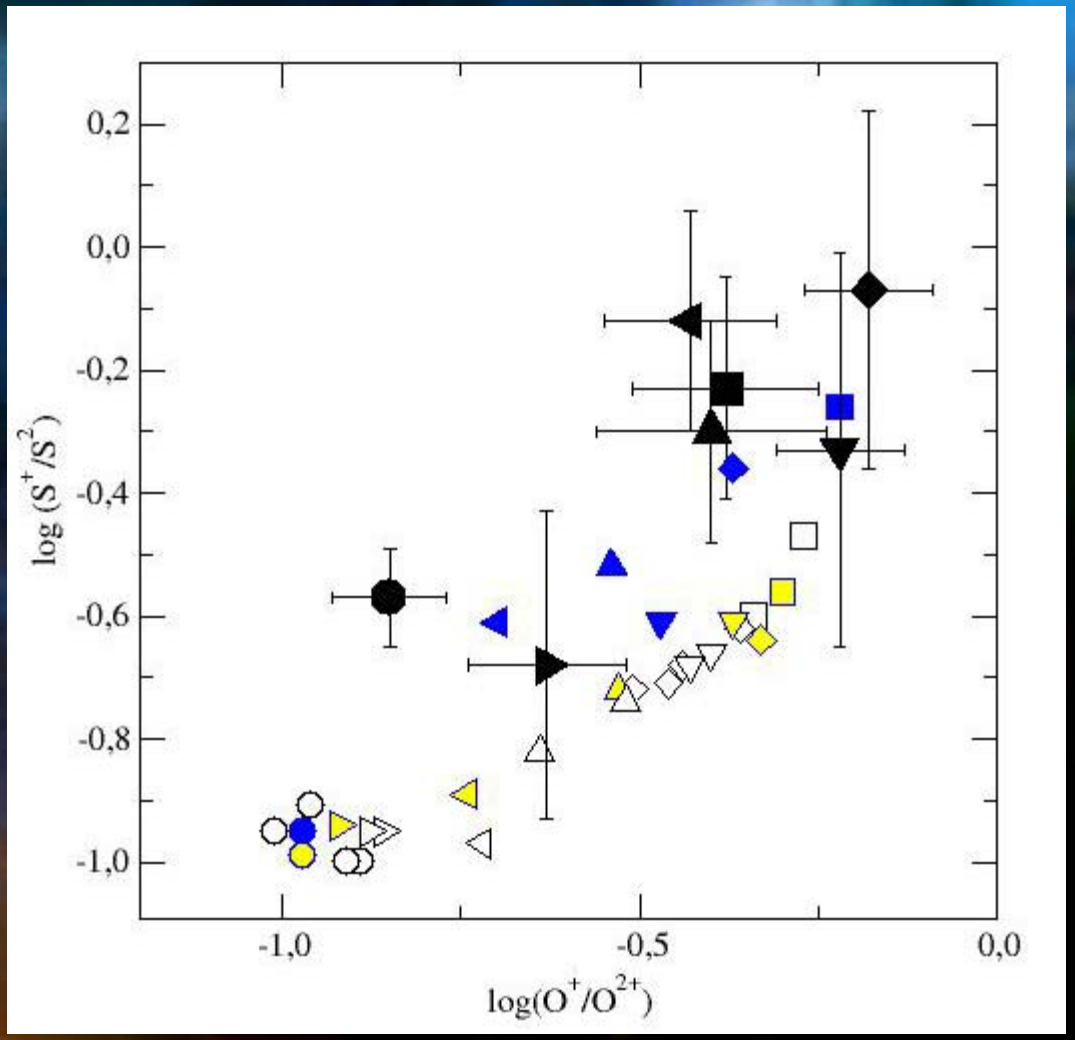


The most important issue resolved about the new models is the agreement between the EW(Hβ) observed and predicted

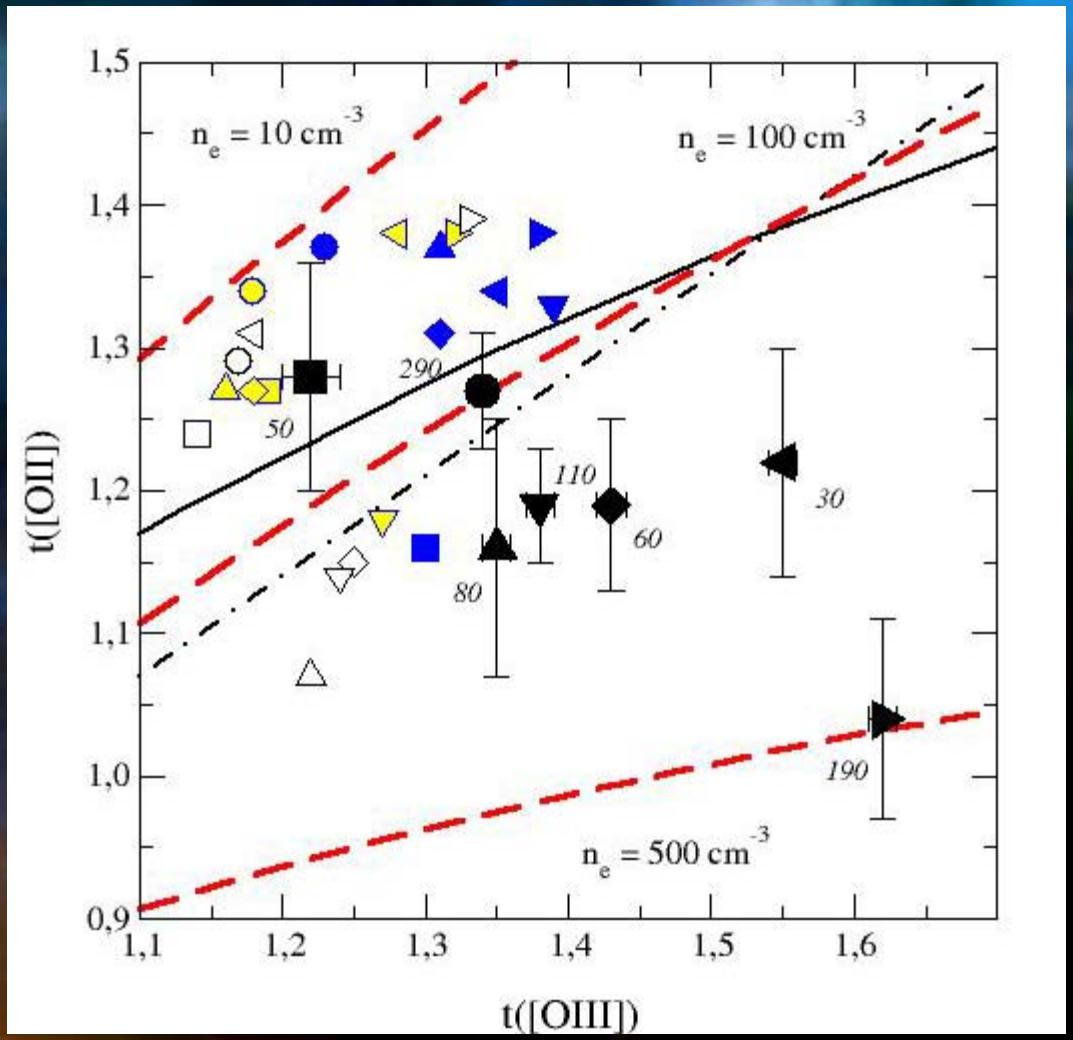


However, the models fail to predict at same time the ionization structure of both oxygen and sulphur.

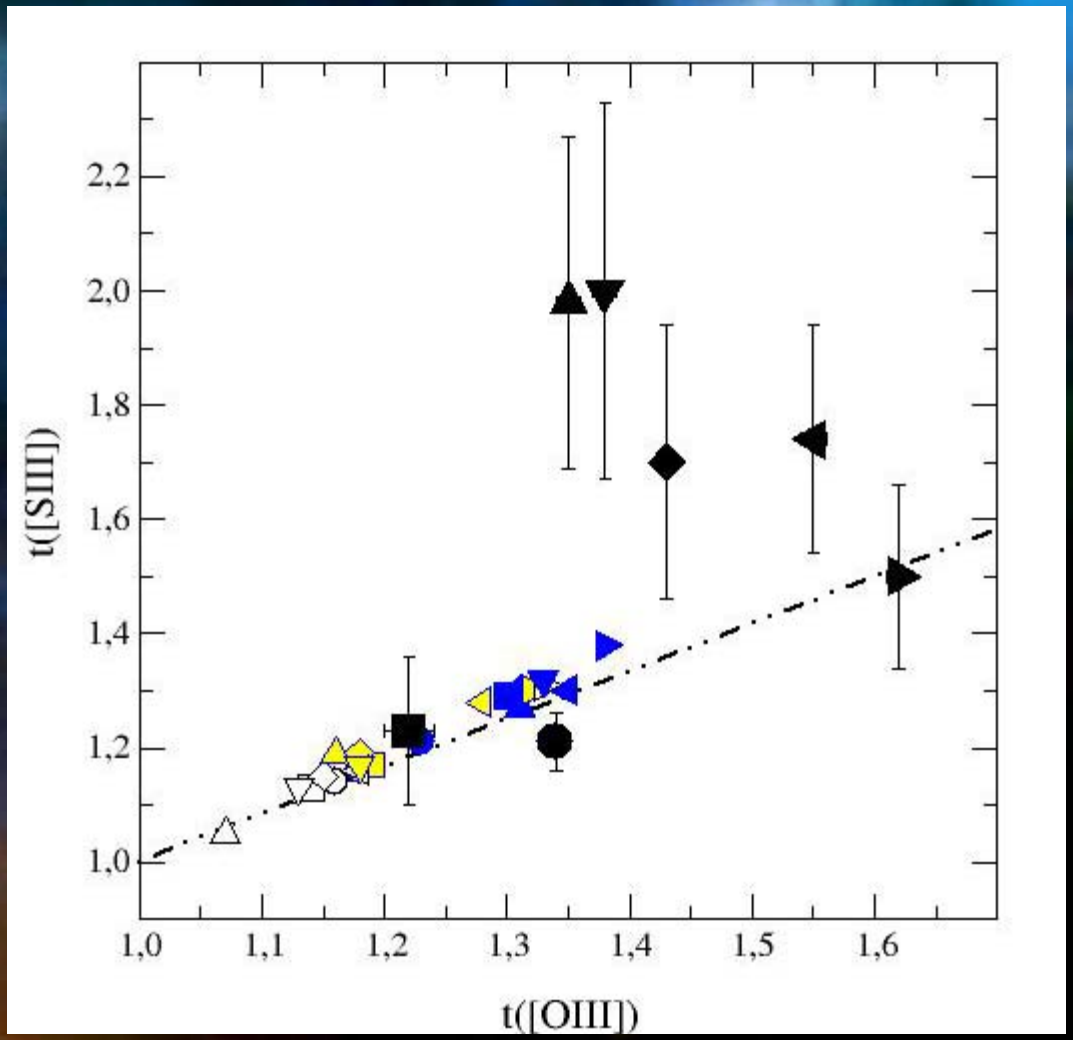
Moreover, the models are not able to fit at same time the nebular and the auroral lines. In this case, the [OIII] 4363 Å, so O^{2+} is always understimated.



t(OIII) are underestimated and keeps a complex relation with t(OII) depending not only on density.



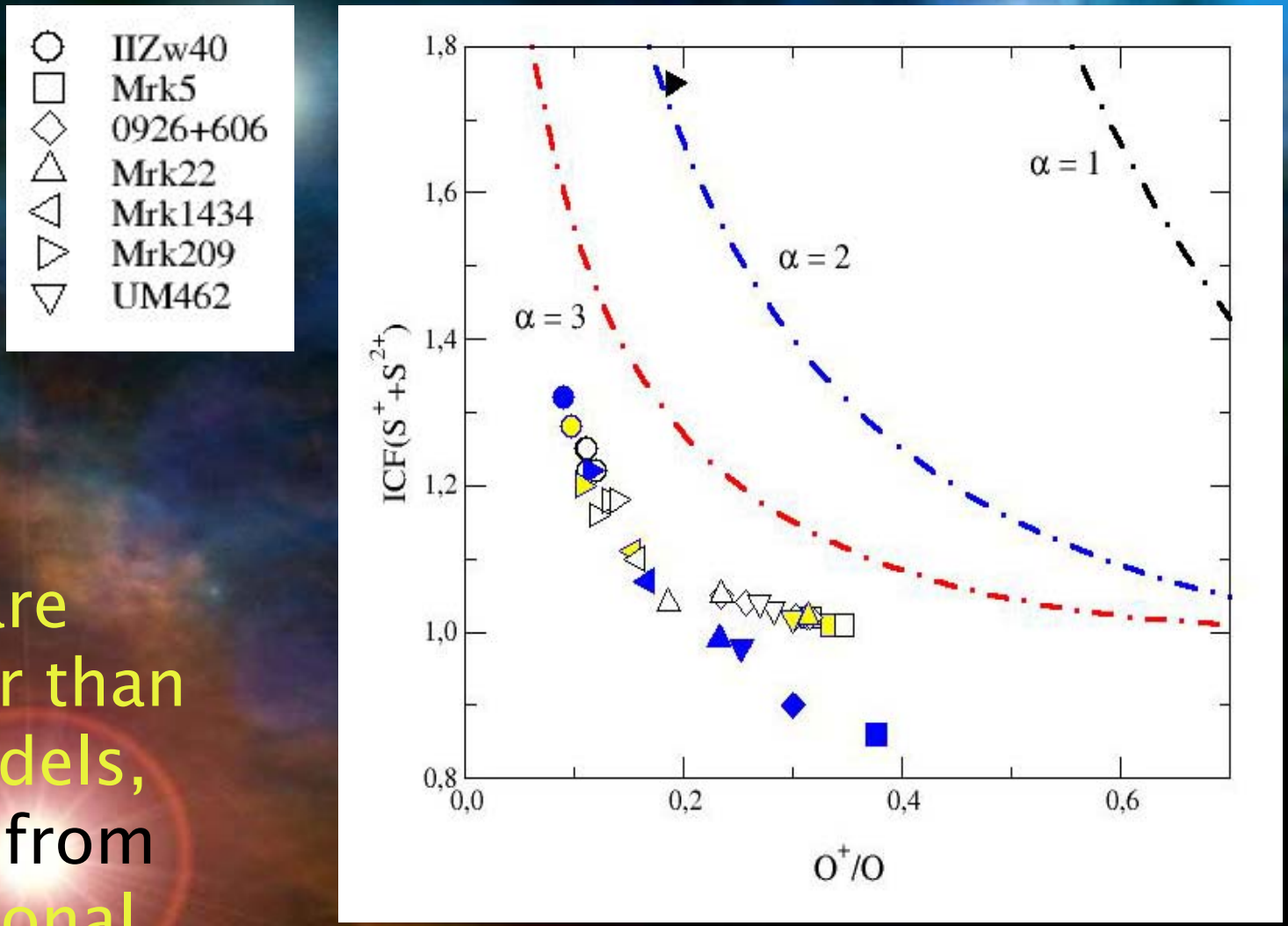
IIZw40
Mrk5
0926+606
Mrk22
Mrk1434
Mrk209
UM462



In relation with the very large values of t(SIII) in some objects, the [SIII] 6312 Å are lower in the models than the observed ones.

Observations
CoStar model
Composite population model
Single population model

Finally, the ICF($S^{+}+S^{2+}$) are slightly larger than in CoStar models, but quite far from the observational point of Mrk209 yet.



Summary and conclusions

✦ We have modelled a set of HII galaxies from their observed properties with the aid of the newest stellar atmospheres as implemented in Starburst99, photometry in B,R and Hα and the features of WR

✦ The best-fitted models point toward the existence of composite populations with similar masses in all the 7 studied galaxies, one with less than 2 Myr and the other between 3 and 5 Myr.

✦ The length and metallicity of both bursts have to be further investigated.

Summary and conclusions

✦ The oxygen lines and the equivalent widths are well reproduced but fail to reproduce at same time the ionization structure of sulphur.

✦ Auroral lines are understimated implying lower electron temperatures and higher chemical abundances.

✦ The amount of S^{3+} is higher than in CoStar models, but it still remains lower than in the only observational point (Mrk209)